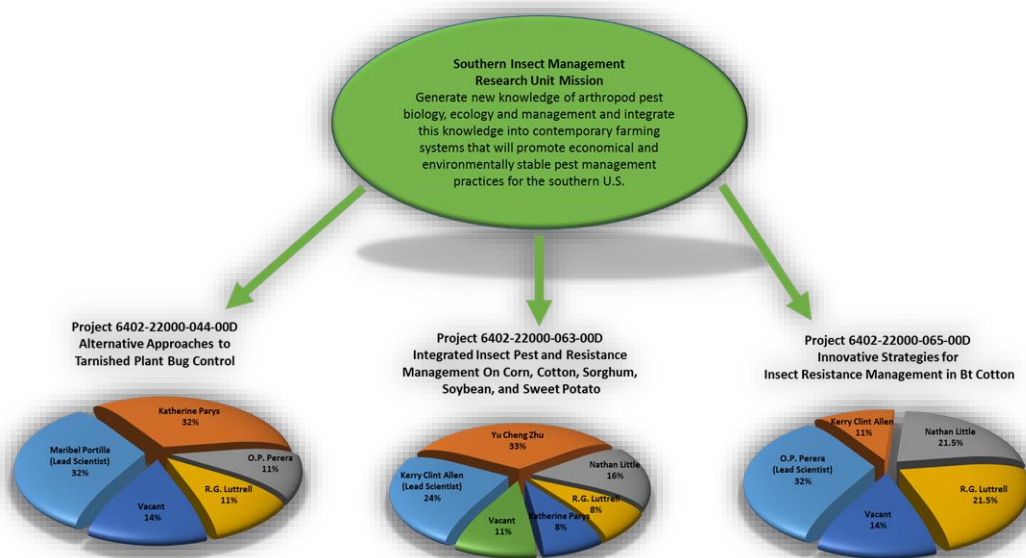




United States Department of Agriculture
Agricultural Research Service Research,
Education and Economics

Southern Insect Management Research Unit Stoneville, MS



***2015 Annual Progress Report
&
2016 Research Plans***

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Mission Statement

**Southern Insect Management Research Unit
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(662) 686-5231**

The mission of the Southern Insect Management Research Unit (SIMRU) is to generate new knowledge of arthropod pest biology, ecology and management and integrate this knowledge into contemporary farming systems that will promote economical and environmentally stable pest management practices for the southern U.S.

The vision of SIMRU is to be a recognized center of innovation for negating agricultural pest problem through deployed scientific knowledge of pest biology, ecology and management options.

Disclaimer and Purpose of Report

This report summarizes progress made on research objectives for 2015 and plans for research activities in 2016.

Many of the results are preliminary and others are being released through established channels. Therefore, this report is not intended for publication and should not be referred to literature citations.

Intent of this report is to give the reader an overview of the Southern Insect Management Research Unit (SIMRU) activities. The activities (progress and plans) address the research unit mission. Formal annual reports of research progress is submitted to the CRIS system are included in the summary.

SIMRU Personnel

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Overall Summary and Perspective of 2015 SIMRU Activities

Collaboration and team work continue to be positive attributes of the Southern Insect Management Research Unit (SIMRU). During 2015, the Unit redefined its research plan for the next five years. Three NP-304 projects were developed and approved. Dr. Clint Allen serves as Lead Scientist for Project 6066-22000-063-00D (**6066-22000-084-00D**) *Integrated Pest and Resistance Management on Corn, Cotton, Sorghum, Soybean and Sweet Potato*. Dr. O. P. Perera serves as Lead Scientist for Project 6066-22000-065-00D (**6066-22000-085-00D**) *Innovate Strategies for Insect Resistance Management in Bt Cotton*. Dr. Maribel Portilla serves as Lead Scientist for Project 6066-22000-064-00D (**6066-22000-088-00D**) *Alternative Approaches to Tarnished Plant Bug Control*. All three received high scores in the OSQR review process, and the framework of these three projects provide significant structure and challenge for SIMRU research through 2020. Project management is increasingly emphasized in the unit, and each Project Leader holds scheduled meetings to review, modify and confirm approaches and progress toward project goals.

Administrative personnel structure became more stable in 2015, but there are still a number of vacancies and challenges with filling vacant positions. The Research Leader returned to the Unit full-time following a year of shared administrative responsibility with the National Biological Control Laboratory. The Area Office became the Southeast Area and expanded from the Delta region formerly defined as the Midsouth Area. Dr. Deborah Brennan was named Area Director. Dr. Jeff Silverstein joined Southeast Area as Associate Director, and Archie Tucker, a former SIMRU employee, was promoted to Associate Director. Mr. Tucker also served as Acting Area Director while Dr. Brennan was on Detail to the Office of National Programs. During 2015, we also experienced a change in ONP leadership. Dr. Rosalind James became a NPL for Invasive Species and replaced Dr. Dan Strickman's oversight of SIMRU projects. Dr. Kevin Hackett and Dr. Roy Scott continue to work with Dr. James to manage the three SIMRU NP-304 projects. Dr. James and Dr. Gene Lester visited SIMRU in January 2015 to familiarize themselves with Stoneville research. SIMRU was instrumental in organizing this interaction and these personal communication channels essential to our research effort.

SIMRU employees are the energy and creativity of the Unit. I am very proud of the current professional and personal atmosphere within the Unit, and I congratulate all SIMRU employees on their unique commitment to collegiality and collaboration. An important component of this positive atmosphere is shared accomplishments. Two of our scientists, Dr. Maribel Portilla and Dr. Clint Allen were promoted in 2015 based on positive evaluations from RPES panels. We are thankful that two of our colleagues, Les Price and Donny Adams, successfully recovered from health events and rejoined our research team during the year. We were also delighted that Dr. Jianxiu Yao and Dr. Mathew Seymour accepted research positions with the Zhu and Perera research groups, respectively, in 2015. Dr. Bryce Blackman, a scientist at IRRI, was recruited in 2015 to begin research with tarnished plant bug in 2016. SIMRU's commitment to student employees is unmatched and legacy of student-mentor relationships for more than five decades. In 2015, SIMRU hired 29 student workers. Priya Chatakondi, a former student worker, joined the unit on a term appointment as a Biological Science Technician. Leslie Bell also joined the Unit on a temporary appointment late in the fall and made significant contributions to our greenhouse facility. Cathy Warren, our longtime PSA, left the Unit to accept a position with HR. We congratulate her on this career change. She will always be a valued member of our SIMRU team. Sakinah Parker was detailed into the PSA position and did an amazing job while still addressing the needs of her permanent OAA position. Lynda Taylor, a former SIMRU and BCPRU PSA, helped us prepare the FY2016 ARMP. The Unit and EBA hosted a retirement reception for Ms. Velma Hoggan, a long-time custodian and friend of SIMRU. The Unit lost a former Research Leader and nationally recognized entomologist in 2015 when Dr. Dick Hardee passed away following a courageous battle with cancer. Nathan Little and Chad Roberts welcomed new sons into their families in 2015.

Several SIMRU employees received recognitions or participated in special activities in 2015. Michelle Mullen was inducted into Mississippi Delta Community College's Sports Hall of Fame. Yolanda Harvey was elected Vice President of EBA. Dr. O. P. Perera served as Acting Assistant Area Director in a detail to the Area Office and was recognized with a Certificate of Appreciation. Nathan Little served as President of the Mississippi Entomological Association, and Clint Allen served as a Director. Larry Adams was the Chair of The National Sweet Potato Collaborators Group, and Randy Luttrell was recognized for contributions to research by Delta Council. Arnell Patterson and Yolanda Harvey were recognized for 15 years of service. Randy Luttrell was recognized for 5 years of federal service. Clint Allen and Randy Luttrell worked with Tom Sappington of the ARS groups in Ames, Iowa and National Programs to evaluate ARS activities and needed research on insecticide treated soybean seed.

SIMRU employees also continue to be active in professional organizations, commodity-support and clientele group meetings, and a number of outreach activities. Dr. Katherine Parys assumed responsibility for studying pollinators in agricultural crops in 2015. She visited the ARS Pollinating Insects – Biology, Management and Systematics Research Unit in Logan, Utah to enhance sampling and pollinator identification skills. The Unit participated in a USDA effort to promote STEAM (Science, Technology, Engineering, Agriculture, and Mathematics) programs and hosted local middle school students in the fall of 2014. Interactions with the Secretaries office continued on evaluation of these programs in 2015. Tabatha Nelson and Yolanda Harvey annually support educational and outreach efforts at Mississippi Valley State University. They were involved with the Youth Motivation Task Force, and Yolanda assisted with the 18th Annual Women in Science and Technology Conference. Larry Adams and Chris Johnson supported a number of activities with Alcorn State University including the Annual Field Data, and an IPM Workshop. Nathan Little, Clint Allen, Larry Adams, Chris Johnson and Randy Luttrell worked with Alcorn State University to host a Leadership Group from the National Black Growers Council at Southern University. Daniel Collins and 25 Alcorn State University undergraduates and graduate students visited SIMRU and explored ARS research activities during the summer. Larry Adams and Chris Johnson annually provide sweetpotatoes from our research plots to the Leland Food Pantry. This gleaning of sweet potatoes was noticed and highlighted in USDA press releases.

The Unit routinely interacts with scientists and agricultural leaders. In the spring of 2015, interviews for a Research Entomologist position included on-site interviews and seminars by Dr. Dale Spurgeon of the USDA-ARS Pest Management and Biocontrol Research Unit in Maricopa, Arizona, and Dr. Julio Medal of the Florida Department of Agriculture. Although the position was not filled, the interaction with these senior scientists was positive. Dr. Tina Teague of the Arkansas Division of Agriculture, Dr. Jack McCarthy with ARS in Starkville, Mississippi, and Bruce Pittman, an active agricultural consultant and representative of the Mississippi Agricultural Consultants Association participated in the interview process. Dr. Frank Davis, a former ARS Research Entomologist, visited SIMRU and worked with Maribel Portilla, Owen Houston and Randy Luttrell to formulate plans for expanded insect rearing capacity. Portilla, Houston and Luttrell also visited Mississippi State University to further discuss new rearing capacity. Visitors to SIMRU in 2015, in addition to those previously mentioned, also included Harold Ikerd from the ARS Pollinator Group in Logan, Utah; Ryan Kurtz of Cotton Incorporated; Sophie Gulliver and Anthony Hawes from Australia; Drs. Al Rankin, Ivory Lyles and Daniel Collins from Alcorn State University; and a number of agricultural chemical and biotech industry scientists.

SIMRU hopes to accelerate research productivity in 2016 and build on the strong internal and external network that was strengthened in 2015. This annual reporting of research activities, research progress and research plans is intended to strengthen these linkages with our valued colleagues and clientele.

Randall G. Luttrell
Research Leader

CRIS Projects

Research Project: *Integrated Insect Pest and Resistance Management on Corn, Cotton, Sorghum, Soybean, and Sweet Potato*

Project Scientists: Kerry Clint Allen (Lead Scientist), Nathan Little, Randall Luttrell, Katherine Parys, Maribel Portilla, OP Perera, Yu Cheng Zhu, Vice-Snodgrass

Project Number: 6066-22000-084-00D

Start Date: July 01, 2015

Project Type: Appropriated

End Date: June 30, 2020

Objectives: The long-term objective of this project is to develop sustainable integrated pest management (IPM) practices for managing insect pests of southern row crops. **Objective 1:** Develop new approaches for the control of noctuid and hemipteran pests of southern row crops, integrating multiple control tactics into integrated pest management systems. **Objective 2:** Minimize negative effects of integrated pest management systems on pollinators and other beneficial arthropods. **Objective 3:** Improve pest risk assessment by determining environmental influences that affect populations of important insect pests of southern row crops with emphasis on bollworms, tobacco budworms, tarnished plant bugs, stink bugs, and soybean loopers. **Objective 4:** Develop methods to measure and manage insecticide resistance of pest populations of southern row crops with emphasis on bollworm, tobacco budworm, tarnished plant bug, and stink bugs.

Approach: Insect management guidelines are generally static from year to year regardless of crop prices, costs of insecticides and yield potential of the crop. We plan to summarize published information for bollworm, tarnished plant bug, and stink bugs and develop economic injury level probability distributions using Monte Carlo simulations. On-farm field evaluations across the Mississippi Delta will evaluate economic returns and environmental sustainability of different insecticidal control strategies in soybean and cotton. Commercially available and experimental sweet potato varieties will be planted annually and the economic impact of insect and nematode control in sweet potato will be examined. The impact of current insect management strategies in southern row crops on populations of pollinators and beneficial insects will be examined in production fields. The surrounding habitats of each field will be documented for plant community composition, focusing on blooming plants that may be of interest to pollinators. Each of these fields will be sampled using a combination of sampling techniques. Community structure will be compared between cropping systems, and related to insecticide applications. We plan to evaluate acute and sub-lethal toxicities and synergistic/antagonistic interactions of honey bees to commonly used pesticides. An examination of gene regulation in honey bees associated with immunity, adaptation, detoxification, digestion/metabolism, and stress-related genes will be conducted after exposure to pesticides with techniques such as real-time PCR, RNAseq or microarrays. Hemipteran and lepidopteran phytophagous pest populations are highly mobile within the landscape and use a variety of weeds and crops as host plants. To examine landscape influences on these insects, the landscape composition surrounding historic and current collection locations will be quantified using Cropland Data Layers (CDLs). Using these CDL layers, buffer zones will be generated around locations. Output data will be tabulated to produce total area of habitat type included within each buffer area and will be related to data collected on insect populations using appropriate statistical analyses. SIMRU will continue to examine susceptibilities of hemipteran and lepidopteran insect pests collected from locations across the Mississippi Delta with a variety of assay methods which may include topically treated diet, residual contact bioassays, glass vial bioassays and a feeding contact assays using floral foam. Insects from original collections will be preserved for molecular analysis using genetic markers. When colonies of any of the pest groups have reduced susceptibility to the tested insecticides, efforts will be made to preserve the colony under a selected and non-selected sequence of exposures to the insecticides of interest. We propose to develop rapid bioassays to predict the

effectiveness of an insecticide application on a real field population of insects. To examine predictive values of laboratory assays on actual field populations, a plot sprayer will be used to deliver a range of formulated product rates on targeted insects.

Summary: Profitable production of row crops in the Southern U.S. generally requires regular use of insecticides. Many of the major insect pests in the Southern U.S. are highly polyphagous and may be exposed to insecticides in multiple crops. A large proportion of the cotton and corn acreage is planted to transgenic varieties expressing proteins from the soil bacterium *Bacillus thuringiensis* (Bt) which alleviates some insecticide applications, but insects are exposed to these Bt toxins over the entire growing season. The heavy reliance on toxicants, both transgenic proteins and insecticides, can lead to resistance and can also decimate non-target arthropods that would otherwise contribute toward control of the pests. . This project will determine optimum economic treatment levels of multiple insect pests, impacts of pest management practices on pollinators, and appropriate means to measure and manage insecticide resistance of important row crop pests of the Southern U.S. It will increase our understanding of the relationship between multiple pests and the rest of the crop ecosystem, potentially emphasizing agronomic practices that reduce the need for pesticide. In designing new, multi-dimensional pest management schemes, there is also the opportunity to reduce negative environmental impacts, such as stress on pollinator populations. Measuring the economic impact of successful new integrated pest management systems and documenting favorable effects on insecticide resistance will show practical advantages to producers who choose to follow more sustainable practices developed by this project.

Research Project: *Alternate Approaches to Tarnished Plant Bug Control*

Project Scientists: Maribel Portilla (Lead Scientist), Katherine Parys, O.P. Perera, Randall Luttrell, Vice-Snodgrass

Project Number: 6402-22000-088-00D

Start Date: December 04, 2015

Project Type: Appropriated

End Date: December 03, 2020

Objectives: Determine key factors that naturally regulate tarnished plant bug population increases and develop new tools for managing tarnished plant bug, including bio-control strategies. Develop novel alternative ways to deploy tarnished plant bug control agents and evaluate effectiveness of these deployment methods in large-scale field experiments.

Approach: The key factors that naturally regulate tarnished plant bug (TPB) population will be determined by collecting feral population from wild host plants, and when available, in cultivated crops at different locations within the Mississippi Delta. TPB nymphs and adults will be collected at each location. Collected insects will be used for microbial and parasitoids identification, molecular identification studies, life table construction, and stable carbon isotope study. Potential entomopathogenic fungi will be bioassayed in replicated laboratory tests and compared with NI8. The most effective fungus will be tested in large-scale field experiments.

Summary: Tarnished plant bug, *Lygus lineolaris* (TPB), continues to have economically important effects on cotton production in the Mississippi Delta and across cotton growing regions of the U.S. with economic losses totaling more than \$100 million each year. Higher levels of resistance to multiple classes of insecticides have become a major concern, resulting in increased insecticide usage and associated ecological concerns. The elevated pest status and impact of a changing agricultural landscape on TPB abundance and distribution warrant additional study to develop alternative approaches that are less dependent upon insecticide use. We plan to identify key factors that naturally regulate TPB populations and explore management options that can reduce population growth before TPB colonizes cotton. We will identify potential microbial agents that infect TPB populations in diverse locations across the Midsouth. These biological control agents will be molecularly characterized, cultured, produced, and tested in both bioassays and field experiments. An important consideration will be the preservation of beneficial arthropods, both predators and parasitoids, which naturally reduce TPB abundance as well as potentially affecting other populations of pestiferous insects. Research with a previously identified fungal biological control agent, a native strain of *Beauveria bassiana* (NI8), will be continued in order to develop selective use strategies in early-season wild hosts and crops. Refinement of these strategies will require additional ecological information; especially landscape level confirmation of TPB distribution patterns to identify targeted hosts for selective deployment of NI8 and new biological control agents. These refinements will be addressed within the scope of our proposed objectives and will be reinforced with collaborative research in other SIMRU projects.

Research Project: *Innovative Strategies for Insect Resistance Management in Bt Cotton*

Project Scientists: OP Perera (Lead Scientist), Kerry Clint Allen, Nathan Little, Randall Luttrell, Vice-Snodgrass

Project Number: 6066-22000-085-00D

Start Date: July 01, 2015

Project Type: Appropriated

End Date: July 30, 2020

Objectives: Determine impacts of Bt toxins on pest insect biology, assess population dynamics, pest behavior, and host-plant relationships that enhance resistance, and develop management strategies to mitigate evolution of insect resistance to host plant expressed insecticidal genes. Determine genetic diversity of bollworm populations and impacts of changes in allele frequencies of loci known to be associated with resistance to Bt toxins and insecticides. Determine impacts of insecticide resistance on management of lepidopteran pests and develop environmentally sound strategies to manage pest complexes in transgenic cropping systems.

Approach: The impacts of transgenic crops producing two or more *Bacillus thuringiensis* (Bt) toxins on population ecology and phenology of bollworm (BW) will be studied using replicated field experiments structured to examine multi-generational effects of selection by different sequences of transgenic crops (Bt-crops) and non-Bt crops. Experiments will be conducted using 1/16th acre field cages during the first three years of the project followed by five-acre field plots during the remainder of the project. Paired treatments will compare Bt-crop varieties with non-Bt counterparts (near isolines). Experimental crops inside cages will be infested with pupae reared from early season larval collections. Insect densities, species composition, survival on a given host, and crop damage data will be used to predict relationships between within-season selection of Bt-crop hosts and the effects of selection on population dynamics of BW. Sentinel plots of cotton and corn will be established on a spatial gradient representative of the range of latitudes within the Mississippi Delta and used to evaluate the effects of supplementary insecticide control of BW on primary Bt and non-Bt crop hosts. Different Bt crop varieties will be paired and planted with a non-Bt isolate. One replication of the Bt variety and its non-Bt isolate will be sprayed with chlorantraniliprole if and when recommended threshold for BW is reached. Other plots will receive no sprays for BW throughout the growing season. Non-target pests on the experimental plots will be controlled as needed with blanket applications of insecticides with no or low lepidopteran activity. Larval collections will be used to determine species composition infesting plots. Crop damage, species composition, and survival from each crop will be analyzed using each location as a replicate in a split plot design to determine the effects of supplementary control of BW in Bt and non-Bt crops on yield. Molecular markers will be used to evaluate genetic diversity of BW populations and impacts of changes in allele frequencies of loci associated with resistance to Bt toxins and insecticides. Allele frequencies in insects collected during the first three years of the project period will be compared with data from insects collected from 2002-2006. Identification of loci under selection will help us evaluate the impacts of field selection on BW over time. In addition, we will be able to estimate the mutation rates of the genes associated with Bt resistance and use those estimates in Bt resistance prediction models. A BW strain tolerant to Bt toxin Cry1Ac will be used to identify genomic regions responding to selection. Impacts of insecticide resistance on management of lepidopteran pests will be determined by mutating target receptor genes to generate insecticide resistance in BW lines with high tolerance to Bt toxins. Fitness costs of dual resistance will be evaluated using controlled experiments. Integrated pest management tactics utilizing various combinations of chemical and microbial agents will be evaluated to develop environmentally sound strategies to the management pest complexes in transgenic cropping systems.

Summary: Original insect resistance management (IRM) plans for transgenic crops expressing *Bacillus thuringiensis* (Bt) toxins to control the tobacco budworm (TBW) (*Heliothis virescens*) and bollworm (BW) (*Helicoverpa zea*) in the U.S. included a high-dose/refuge strategy to slow the development of resistance. With introduction of crops expressing pyramided or chimeric toxins, the mandatory within-crop-refuge

requirement was replaced by natural refuges consisting of wild hosts and non-transgenic crops. These new transgenic crops expressing multiple or chimeric Bt toxins provide additional hurdles for pest resistance, but still lack high-dose expression for important pests like BW and potential new pests like “Old World” bollworm (OWBW) (*Helicoverpa armigera*). Insecticide sprays are often required for economic management of BW in Bt cotton. Expanded acreages of Bt corn have increased exposure of BW to Bt toxins, and new Bt crops (e.g. soybeans) are being considered that would further lessen natural crop refuge in the U.S. To effectively manage resistance to Bt toxins, additional knowledge of pest biology, ecology, toxin dose, and effectiveness of refuges is needed. Data on performance of chemical and natural insecticides are also needed as they are important components of management systems that could lessen selection for Bt resistance and still maintain crop protection. With widespread OWBW invasions in South America, North America is at high risk of invasion by this serious pest with known propensity to evolve resistance to insecticides and Bt toxins. Research proposed in this project addresses critical questions associated with IRM and builds a base of information for alternative management options.

2015 Research Program Accomplishments

Adams Research Program

Participated in the 2015 NSCG Sweetpotato variety trials at the Alcorn State University Research Farm in Mound Bayou, MS. Compared yield and quality of seven sweetpotato varieties grown in the Mississippi Delta; Beauregard 14, Covington, Orleans, Bayou Belle, Burgundy, Bellevue and a NCSU experimental line, NC05-198. Average yield for all varieties in 2015 was 403 US#1 bu/A. Bayou Belle, Burgundy, and Bellevue were the top yielding varieties. The North Carolina experimental variety, NC05-198, was average and comparable to the North Carolina variety, Covington, in yield and quality. **(L. Adams, C. Johnson)**

Completed an insecticide efficacy trial to control fall armyworms in sweetpotato during the 2015 growing season. Fall armyworm egg masses obtained from the USDA-ARS, SIMRU rearing group were released in sweetpotato plots at the ASU Research Farm at Mound Bayou, MS and larvae hatch was monitored to determine the survival of a damaging population of armyworms. Six recommended insecticides were evaluated; Coragen, Besiege, Intrepid, Diamond, Radiant and Mustang Max. Sweep net samples were taken three days after the insecticide applications and compared to an untreated control. Damage from the fall armyworm was significantly different in all treatments when compared to the untreated control. Coragen was the most effective treatment with no damage observed. Fall armyworm damage ranged from 0 to 23 percent in this study. **(L. Adams, C. Johnson)**

SIMRU continued collaborative research with Alcorn State University scientists studying sweetpotato insect identification, sampling and damage in the Mississippi Delta. We collaborated with Dr. Tahir Rashid comparing yield and insect damage to organic sweetpotatoes in the Mississippi Delta. Several sweetpotato varieties were transplanted to study organic farming results in sweetpotato including All Purple, a traditional Japanese variety, Beauregard, Porto Rico, and O Henry. Each variety was planted in 4 replicated plots on two rows. There were 10 plants in each row. Drip irrigation was used as needed until plants were established. Weeds were removed with a gas powered push tiller, hoe and with a tractor tiller. Insect pests were monitored with purple and soil bait traps. All treatment plots were harvested at maturity and evaluated for insect damage and yield. O'Henry provided the highest yield compared to all other varieties. Overall insect damage was highest in Porto Rico where 43% roots were damaged followed by Beauregard (38%), 'O Henry' (26%) and the least damage occurred in All Purple where only 13% roots were damaged by insect feeding. This study concludes that some organic sweetpotato varieties may be adaptable to local environment in the Mississippi Delta. **(T. Rashid, L. Adams, C. Johnson)**

We collaborated with Dr. Tahir Rashid to complete further testing of an Amerimac Chemical Company foliar feed product, SumaGrow, in sweetpotato production. Research trials were conducted to evaluate a microbial formulation SumaGrow® containing more than 26 strains of beneficial naturally occurring soil microbes. These microbes are expected to protect both soil health and prevent nutrient leeching thus providing enhanced plant root and shoot growth which results in higher yields, nutrient density, and increase in plant resistance to the pests and disease. The sweetpotato variety Beauregard was planted in experimental field plots each containing 4 rows of 50 feet. Microbial treatments were randomly assigned to 6 plots. Same numbers of plots were untreated which served as the control. The SumaGrow® formulation was applied at 0.5 gallon per acre rate twice during the season after 10-days and 30-days of planting. Insect populations were monitored with sticky traps installed around the field and checked biweekly. Three sweetpotato plants along with the roots were excavated from each plot every two weeks to record differences in growth over time. Root diameter and vine lengths of each plant were measured and weighed. Roots were checked for any insect damage. No significant difference was observed from insect damage, foliage, root or yield data. **(T. Rashid, L. Adams, C. Johnson)**

SIMRU has monitored and reported populations of *H. zea* and *H. virescens* in the Mississippi Delta through pheromone trapping since 1992 and completed the 23rd year in 2015. In 2012 SIMRU moth trapping recorded a jump in *H. zea* moth captures from previous years since the introduction of transgenic crops. During 2015

the upward trend continued with an average number of moths per trap per week peaking at 117 in late July. *H. virescens* captures remained relatively low throughout the season. Weekly data were provided to the Mississippi Cooperative Extension Service from Washington and Bolivar counties. (**L. Adams, C. Johnson**)

We assisted with other USDA-ARS, SIMRU scientists with two studies: 1) a field study on the use of *Beauveria bassiana* for control of tarnished plant bugs in mustard, corn and cotton, and 2) small plot studies to study the effect of imidacloprid seed treatment on honey bee movement and foraging in cotton, corn and soybean plots. We planted, maintained the plots, collected and processed data and harvested yield samples for both studies at the Alcorn State University Research Farm in Mound Bayou, MS. (**R. Luttrell, N. Little, C. Allen, M. Portilla, L. Adams**)

Allen Research Program

Wild host plants are important to the early season build-up of many of the important insect pests of southern row crops. Early season wild-hosts were sampled across the Delta to examine the importance of these hosts in the build-up of stink bugs before they move into soybean. Heliothine species were collected and reared to identify species. More stink bugs were collected from various species of clover, especially crimson clover, than any other wild host. Redbanded and southern green stink bugs were only collected from the central and southern Delta counties, but populations were fairly low compared to other years. The majority of heliothines collected were corn earworms, but tobacco budworms made up approximately 22% of the population at one collection location. (**C. Allen, L. Andrews, N. Little**)

As soybean acreage has increased across the state in the last ten years, crop inputs including insect control has intensified. We examined the economic benefit of insecticide inputs at various population densities of heliothines and loopers, especially in late-planted dry land soybeans where the yield potential is normally much less than that of earlier planted irrigated soybeans. Heliothine populations were treated with a pyrethroid and diamide insecticide on three different dates 2-3 days apart. Although there can be mixed populations of tobacco budworms in soybeans, almost all of the heliothine larvae collected were bollworms. Soybean loopers were treated with different rates of multiple classes of insecticides. These studies are being continued in 2016. (**C. Allen, N. Little, L. Andrews**)

Action thresholds for stink bugs were examined on the Southern Insect Management Research Unit farm in Washington County, MS. Small plots were sampled weekly for numbers of stink bugs. Treatments included action threshold levels of 0, 3, 6, 9 stink bugs per 25 sweeps and an untreated check. Plots were sprayed when needed from the R3 through R7 growth stages. All treatments were triggered by stink bug densities with the exception of the 9 stink bugs per 25 sweeps. Yields ranged from 36-43 bushels per acre, but there were no significant differences between treatments. There were also no differences for damage and oil content of soybean seed samples from the various treatments. (**C. Allen, N. Little, L. Andrews**)

The impact of insecticide treated corn, cotton, and soybean seed on early-season insect populations were examined at three locations. Leaf tissues were excised periodically and the amount of insecticide was measured. Additionally, native bee and pollinator diversity in treated and untreated soybean were examined in approximately 4 acre plots in Washington County, MS. Data are being studied and are no available observations at this time. (**C. Allen, L. Adams, C. Johnson, K. Parys, N. Little, L. Andrews, R. Luttrell**)

Little Research Program

The percentage of Bt cotton acreage receiving supplementary control applications for the control of heliothines over the past several years has increased. Our investigations of non-Bt and pyramided-gene Bt

cottons under sprayed (threshold) and unsprayed conditions have continued. This study included establishment of numerous sentinel plots, which served as a geographic representation of the MS Delta farming region. This study is ongoing, and data collection and analyses are not complete. Upon conclusion, the information gained from this study will be used to assess the performance of new and existing pyramided-gene Bt technologies in field environments. **(N. Little, D. Adams, C. Allen, and R. Luttrell)**

The diamides are a highly efficacious class of chemistry for the control of heliothines, and their use is increasing for supplementary control situations in Bt cotton across the MS Delta. The residual efficacy of different formulations within this class of chemistry differ, however. This study examined the residual activity of different diamides and other conventional insecticides with regard to crop damage under different insect pressures in Bt and non-Bt cottons. Although data for this study have not been analyzed, it will provide an economic benchmark for the use of diamides in supplementary control situations in Bt cottons. **(N. Little, C. Allen, R. Luttrell, and D. Adams)**

The nonbinding site proteinases (esterases and glutathione S-transferases) were studied to ascertain the impact of Bt corn and cotton on *H. zea* and to evaluate the physiological non-target impacts of multiple exposures to transgenic crops producing two or more Bt toxins. Each developmental instar of larvae of *H. zea* from Bt and non-Bt corn and cotton were assayed for esterase activity using α -naphthyl acetate or β -naphthyl acetate and 0.06 % Fast Blue B salt as substrates. Glutathione S-transferase activity of samples was assayed using 1-chloro-2,4-dinitrobenzene (CDNB) as substrate. In both instances there was a several fold increase in enzyme activity in 1st instar larvae compared to later instars upon exposure to Bt corn. We are now in the process of verifying if expression of genes encoding for esterase, GST1 as well as cytochrome P450 monooxygenases (CYP4) follow a similar pattern using quantitative real time polymerase chain reaction. **(N. Little, N. Krishnan, and D. Adams)**

Microbial insecticides were evaluated to determine whether natural pesticides can produce environmentally sound management of heliothines in cotton. These natural pesticides were applied in an undisturbed cropping system (ie. no synthetic insecticides were applied for the control of non-target pests) to determine its feasibility as alternative control measures for heliothines in transgenic cotton. Microbial insecticides were evaluated in large sprayed and unsprayed field plots and evaluated against commonly used insecticide regimes. This study began in 2015, and only a single year of data has been collected, so the breadth of data collected for this study is not currently suitable for statistical analyses. However, preliminary data indicate that microbial insecticides may be more effective when utilized in undisturbed cropping systems than when used in combination with synthetic insecticides for heliothine control. **(N. Little, R. Luttrell, C. Allen, D. Adams)**

An economic cost/benefit analysis of growing transgenic Bt corn for control of corn earworms was evaluated in 2014-2015 in collaboration with multiple scientists from other institutions. We are currently entering the final year of data collection for this study. Bt and non-Bt events were examined for numbers of corn earworms and the resulting impacts on yield. Upon the conclusion of this study, we anticipate a manuscript on the cost/benefit of planting transgenic Bt corn for earworm control in the MS Delta. **(N. Little, D. Cook, and D. Adams)**

Luttrell Research Program

Neonate and third instar *Helicoverpa zea* (Boddie) larvae were exposed to microbial and chemical insecticides on non-Bt (DP1441) and Bt (DP1321) cotton leaves in spray-table experiments. With neonate *H. zea* exposed

to Dipel, Gemstar, Karate, and Prevathon, significant treatment by plant tissue interactions ($P < 0.0001$) were detected at all posttreatment observations (5, 10, and 20 days). There was no survival of neonate *H. zea* exposed to any of the application rates of Karate or Prevathon, including those 1/27th that of the recommended high rate. Mortality of larvae on untreated Bt cotton at 5 days (68.3%) was less than that of larvae exposed to Karate or Prevathon on Bt and non-Bt cotton (100%) but greater than that of larvae exposed to non-Bt cotton treated with the lower two rates of Dipel (16.7 and 35%) and all rates of Gemstar except the 10 oz/a rate (48.3%). By pupation at 20 days posttreatment, mortality of larvae exposed to the highest rate of Gemstar on non-Bt cotton (98.3%) was comparable to that observed with Karate and Prevathon. With 3rd instar *H. zea*, all treatments on Bt cotton at 5 days posttreatment, including untreated Bt cotton, had higher mortality (75 to 100%) than that observed for the untreated non-Bt cotton (21%). All treatments applied to non-Bt cotton with the exception of the two lower rates of Gemstar (0.11 and 1.1 oz/acre) had higher mortality (50 to 100%) than that observed for insects on untreated non-Bt cotton. All treatments had greater cumulative mortality at pupation (20 days posttreatment) than that observed for untreated non-Bt cotton (31%). Treatments with less cumulative mortality at pupation than that observed for untreated Bt cotton were non-Bt cotton treated with the two lower rates of Gemstar (0.33 and 1.0 oz/acre) applied to Bt cotton. All treatments applied to Bt cotton, except the three lower rates of Dipel (0.11, 0.33 and 1.0 lb/acre), had cumulative mortality at 20 days posttreatment equal to Karate and Prevathon treatments and greater than that of untreated Bt cotton (83.3%). **(R. G. Luttrell, Michelle Mullen, Nathan Little, Clint Allen, O.P. Perera)**

A spray-table study was conducted to compare activity of Dipel and Karate against neonate *H. zea* and *H. virescens* to that obtained with different commercial formulations of *Heliothis* nuclear polyhedrosis virus on non-Bt cotton. No significant interactions were observed between treatments and species. At the 5 day posttreatment observation, treatment ($p < 0.0001$) and species ($P = 0.0251$) effects were significant. At all other observation times, only treatment effects were significant ($P < 0.0001$). With *H. zea* observations at 5 days, treatments with higher mortality than untreated non-Bt cotton included all three rates of Dipel (0.11, 0.33 and 1 lb/acre), the two higher rates of Gemstar (3.3 and 10 oz/acre), the highest rate of Heligen (2 oz/acre), and both rates of Karate (0.00256 and 0.0256 oz/acre) which were 1/1000th and 1/100th of the recommended rate. With *H. virescens* observations at 5 days posttreatment, the three rates of Dipel tested (0.11, 0.22, and 1 lb/acre) and the highest rates of Karate tested (0.256 oz/acre or 1/10th the recommended rate) had more mortality than the untreated non-Bt cotton. By 14 days posttreatment, all treatments except the lowest rate of Elcar (2.2 gm/acre) had higher cumulative mortality than the untreated non-Bt cotton infested with *H. zea*. Similar trends were observed with *H. virescens*, but few virus treatments were significantly different than that of *H. virescens* exposed to untreated non-Bt cotton (36.1% mortality). **(R. G. Luttrell, Michelle Mullen, Nathan Little, Clint Allen, O.P. Perera)**

Residual activity of Dipel, Gemstar, Karate and Prevathon on cotton leaves in a small-plot field experiment was measured by assay mortality of *H. zea* larvae at different times posttreatment. The recommended rate of Prevathon (27 oz/acre) showed no reduction in residual activity on cotton over the 16-day test period. The reduced rate of Prevathon (0.27 oz/acre) 1/100th the recommended rate showed a significant reduction at the 16-day observation. The full rate of Karate (2.56 oz/acre) showed reduced activity at the 16-day observation, and the reduced 1/100th recommended rate (0.0256 oz/acre) showed reduced activity at 1-day posttreatment. The Dipel (1 lb/acre) and Gemstar (10 oz/acre) treatments had reduced residual activity after 1-day of exposure to the field environment. **(R. G. Luttrell, Michelle Mullen, Nathan Little, Clint Allen, O.P. Perera)**

Small plot field studies were conducted on the SIMRU research farm and the Alcorn State University research farm to measure differences in cotton, corn and soybean plots planted with imidacloprid treated and untreated seed. Observations included numbers of thrips, plant biomass, levels of imidacloprid in foliage, and yield. Efforts were also made to weekly scout the plants for any observable insects. A large-plot study was also conducted in a commercial field of late-planted soybean where the same observations were made. The large-plot study also included measurements of pollinators in plots planted with imidacloprid treated and untreated

seed. Analyses of the data are continuing, but a few general observations were made. Difference in numbers of thrips were measured on cotton and soybean with fewer numbers in the plots planted with treated seed at different times post planting of the crops.. Differences in weighted biomass of foliage and visual assessment of cotton, corn, and soybean small plots were also observed at a few periods post planting. Yield differences were only measured in cotton with the plots planted with treated seed having higher yield than the plots with untreated seed. No differences in yield of corn and soybean plots were observed. Results are preliminary. These studies will be continued in 2016. **(R. G. Luttrell, Clint Allen, Larry Adams, Chris Johnson, Nathan Little, Katherine Parys)**

Following Gordon Snodgrass' retirement in 2014, routine collections of tarnished plant bug were made from preferred wild hosts to provide insects for laboratory assays measuring evolving levels of insecticide susceptibility in field populations of tarnished plant bug. These field collections began in the spring of 2014 and are still being conducted. In October 2014, a more detailed tracking of insect numbers collected was established and insects were also provided for life-table studies described by Maribel Portilla and Katherine Parys. Arnell Patterson made most of the collections. Kenya Dixon conducted insecticide assays with the field-collected bugs exposed routinely to acephate, imidacloprid, permethrin, and thiamethoxam. Procedures were the same as those previously used by Gordon Snodgrass. Studies in 2015 also included initial assays of sulfoxaflur. From October 2014 through December 2015, more than 45,000 tarnished plant bugs were collected and brought to the laboratory for insecticide assays. Of these, about 80% were adult tarnished plant bugs. This effort included 100,826 sweeps with about 0.35 adult and 0.09 nymph tarnished plant bugs per sweep. A diversity of different host plants were sampled. Erigeron, pigweed, marehail, and ragweed provided high numbers of insects for the study. More bugs were collected during the spring, summer and fall than in the winter months. Peak abundance as measured by mean number of bugs per sample site was in April. Only a few bugs were collected during December. Average LC50s from statistically significant regressions expressed as ug of insecticide per vial (glass vial surface treatment or floral foam exposure in vial following Snodgrass procedures) were 15.5, 1.5, 5.1, and 3.5 for acephate, imidacloprid, permethrin, and thiamethoxam in 2014. In 2015, the average LC50s were 7.4, 1.7, 1.6, and 2.2, respectively. The average LC50 for sulfoxaflur in 2015 was 8.9 ug/vial. A number of populations did not respond to the tested concentrations in a predicted manner, and additional study of these data are underway to investigate possible indication of evolving resistance. Also, the discriminating dose assay for permethrin (as defined by Snodgrass) was conducted in 2014, and all of tarnished plant bug assay data since 2008 is being compiled for a historical summary. **(R. G. Luttrell, Arnell Patterson, Kenya Dixon, Maribel Portilla, Katherine Parys)**

Plots of cotton were planted adjacent to plots of corn and mustard on the Alcorn State University research farm and the SIRMU research farm to study possible control of tarnished plant bugs by spraying the corn with *Beauveria bassiana* prior to their movement to the adjacent cotton. Mustard was planted as a nurse crop to build tarnished plant bug numbers prior to the tasseling of corn. The idea was to build tarnished plant bug densities in the mustard, cut the mustard and move the bugs to tasseling corn, treat the corn with *B. bassiana*, and measure impacts on cotton. The experimental design was a Latin Square with three replicates of corn and cotton untreated, a corn only treated, and a corn and cotton treated with the NI8 strain of *B. bassiana* (10^{12} conidia per acre). This study was a continuation of a replicated field study initiated in 2013. Timing of the mustard and corn plantings were impacted by a wet spring at both locations. Tarnished plant bug numbers were supplemented by collecting thousands of bugs from wild hosts and releasing them in the corn plots at early silk stage. Plant bug densities were monitored by beat net and sweep net samples. Treatment inoculum and spray deposit was measured by assay of the treated tissue in the laboratory and assessing spray deposits on treated cover slips. Results were variable and a general confirmation of the previous 2013 study. Infection of tarnished plant bugs was measured from the treated foliage, although there appeared to be some contamination of plots, possibly drift in the small-plot study area. Differences in tarnished plant bug numbers were noted on a few sample dates immediately following treatment, but the differences were not large and the bugs appear to leave the small-plot treated area. It appears that larger plots are necessary to measure

plant bug suppression by the entomopathogenic fungus. **(R. G. Luttrell, Maribel Portilla, Larry Adams, Chris Johnson, Tabatha Nelson)**

Laboratory and spray-table studies were conducted with *Helicoverpa zea*, *Heliothis virescens*, and *Lygus lineolaris* to explore options for comparing Bt and non Bt cotton tissues and insecticide treated and untreated cotton tissues. Studies were conducted with different sizes of plant tissue including whole intact leaves and core plugs of leaf samples of varying size. Small (paper punch size $\sim \frac{1}{4}$ "diameter) leaf discs were appropriate for neonate larvae, but did not provide sufficient food for larvae to survive beyond three or four days. Larger leaf discs (approximate $\frac{3}{4}$ "diameter) provided sufficient leaf material for five to seven days. All leaf substrates were kept moist by placing the leaf tissue on the surface of agar in a 1 oz plastic cup capped with a plastic lid. This procedure also worked well for assays of tarnished plant bug exposed to leaves dipped in varying concentrations of formulated insecticide. Experiments conducted in 2016 to measure the amount of insecticide solution on leaf discs following submersion in water diluted concentrations, suggested that the dipping procedure would potentially represent a spray volume of 200 gpa. Additional assays with the lepidopteran pests are being conducted by Michelle Mullen in Nathan Little's laboratory, and Clint Allen is investigating the leaf dip as a possible assays for studying lepidopteran susceptibility to insecticides. Kenya Dixon is completing a series of experiments with tarnished plant bug exposed to a range of doses of the insecticides included in annual resistance monitoring of the pest. These studies may be useful in improving the projection of field exposure of insects to treated cotton and soybean. The Little laboratory is further developing the procedure as a possible mechanism to estimate the amount of Bt toxins consumed by lepidopteran larvae. **(R. G. Luttrell, Michelle Mullen, Kenya Dixon, Nathan Little, Clint Allen, Maribel Portilla)**

Parys Research Program

An active sampling program was established to determine the first appearance of *Lygus lineolaris* nymphs (F1 generation) across a large geographic area spanning from Texas to North Carolina. This phenological data will be used to evaluate the accuracy of degree-day models previously constructed using historical weather data from the local area of Stoneville, MS. This wider range of geographic coverage will enable us to determine if models constructed on a local area are applicable on a wider scale. Data will be analyzed after collections are made in the spring on 2016. **(K. Parys, M. Portilla, N. Little, K. C. Allen, R. Luttrell, J. Esquivel, D. Kerns, G. Lorenz, S. Stewart, F. Musser, F. Reay-Jones, J. Greene, D. Reisig)**

Collections of native apoid pollinators were made in a variety of agricultural produced commodities including commercial fields of corn, cotton and soybeans located in Indianola, MS, as well as plot sized rice and sorghum located on the Delta Research and Extension Campus in Stoneville. Additional specimens were collected from selected non-agricultural areas including fallow fields, roadside ditches, the stoneville woods, and Tallahatchie National Wildlife Refuge. Samples were taken using a combination of bee bowl units, malaise traps, and sweeping to document species richness and abundance. Additional specimens were added from bycatch of other studies including moth pheromone traps. Over 8,200 specimens were cleaned, pinned, mounted, and entered into a database. Identification and taxonomic resolution of specimens is ongoing. **(K. Parys, N. Little, K. C. Allen, M. Portilla, R. Luttrell, D. Cook, J. Gore)**

Field collections of 500 sweeps in areas with known populations of *L. lineolaris* were made weekly, in a variety of habitats and geographic areas across the delta region of Mississippi, Louisiana, and Arkansas. These samples were returned to the lab for a variety of studies and to provide genetic material. These samples were frozen, and preserved to identify insect population densities and evaluate the samples for biodiversity. **(K. Parys, M. Portilla, R. Luttrell, A. Patterson, L. Price)**

Both adult and nymphs of *L. lineolaris* were removed from the samples collected above and subjected to stable carbon isotope (SCI) analysis. This analytical technique has the ability to differentiate between insects that developed on C₄ hosts (corn and pigweed) and C₃ hosts (most broad leaved plants, including soybean and cotton). Approximately 20 adults and up to 20 nymphs were removed from each of the collections of 500 sweeps made across the delta. Samples are currently being processed and data from the first year of collections is being evaluated. **(K. Parys, L. Price)**

A suite of oral biomarkers were evaluated for use in marking *L. lineolaris*. Of the seven dyes evaluated, none reliably marked nymphs or adults when viewed under a standard white light, regardless of feeding times. Of the dyes tested, those that were red/pink were better markers under white light than other colors, but natural variation amongst individuals within the natural population of *L. lineolaris* includes a red eyed biotype. Using a Green fluorescence filter, nymphs that ingested honey solution with Rhodamine B, Safranin O, and Acridine Orange were marked at 24, 48 and 72 hrs. Nymphs that ingested the control honey solution or solutions containing Auramine O, Fluorescein sodium salt, Carmoisine, Indigotine were not reliably marked at 24, 48 or 72 hrs. Adults that ingested honey solution with Rhodamine B and Safranin O were all marked by 72 hrs, but those that ingested Rhodamine B were not well marked at 24 or 48 hrs. Those adults that ingested the control honey solution or solutions containing Acridine Orange, Auramine O, Fluorescein sodium salt, Carmoisine, Indigotine were not reliably marked at 24, 48 or 72 hrs. Preliminary results of this study indicate that Safranin O, Rhodamine B, and Acridine Orange are potentially useful as oral biomarkers for *L. lineolaris* when incorporated into a honey water solution. **(K. Parys, T. Mascari, M. Portilla)**

Perera Research Program

A handful of genes involved in the mode of action of *Bacillus thuringiensis* (Bt) toxins and mechanisms conferring of tolerance have been identified in corn earworm and tobacco budworm. These genes include aminopeptidases, membrane-bound alkaline phosphatase, cadherins, and ABC transporters and are considered as contributors of large effects to Bt toxin tolerance. It is hypothesized that there are a number of yet unknown genetic loci with small additive effects that also contribute to tolerance to Bt toxins. In order to identify genes co-expressed during Bt intoxication, gene expression profiles were used to identify gene regulatory networks in Cry1Ac fed tobacco budworm *Heliothis virescens*. Previously assembled transcriptome of *H. virescens* was used as the reference to identify differentially expressed genes in the 4th instar larvae of susceptible YDK strain fed on Cry1Ac toxin for 120 and 480 minutes compared to controls (fed on buffer only). The analysis identified several co-regulated gene networks that included genes known known to be associated with resistance to Bt toxins. **(O. Perera, Mathew Seymour)**

Old-world cotton bollworm (*Helicoverpa armigera*) invaded Brazil in 2012 and has now spread to some of the neighboring countries in South America. Animal and Plant Health Inspection Service (APHIS) of USDA documented capture of *H. armigera* in Puerto Rico in September 2014. Recent detections of *H. armigera* OWB in Florida and Louisiana indicate that it has reached continental North America. Pheromone lures for OWB attract BW and trap captures include large numbers of BW. Previous detection methods relied on examination of male genitalia or sequencing mitochondrial DNA and are labor intensive, time consuming, and expensive requiring high level of expertise. Detection method that uses a simple buffer to obtain a homogenate from a small amount of tissue (e.g. a moth leg, a neonate, or an egg) eliminating the need for lengthy DNA extraction procedures was developed. High resolution melt (HRM) analysis of species-specific DNA fragments facilitated detection of a single OWB in a pool of up to 25 insects using only a 1 µl of homogenate. Pooling facilitated analysis of up to 2,400 insects using 96-well plate format and up to 9,600 insects using 384-well plate format in about 90 minutes. The technology was transferred to USDA-APHIS through an interagency agreement. This technology will be used by USDA-APHIS PPQ as well as state and university monitoring programs to identify invasive *H. armigera* in the USA. **(O. Perera, C. Pierce, P. Chatakondi)**

The perception and discrimination of odorants and other chemical cues in insects require odorant-binding proteins (OBPs) and chemosensory proteins (CSP) and odorant receptors. OBPs and CSPs bind chemical ligand and facilitate triggering of receptor combinations specific to the each class. We previously characterized and published the OBP repertoire of the tarnished plant bug, *Lygus lineolaris*. CSP repertoire of *L. lineolaris* and *L. hesperus* was identified using a transcriptomics-based approach. In addition, antennal transcriptomes of *L. lineolaris* before and after sexual maturity were also characterized to evaluate changes in gene expression patterns during sexual maturation of adult *L. lineolaris*. Sensory genes and receptors involved in mate localization could be disrupted by ligands that are specific to *Lygus* species to avoid affecting non-target species by control measures directed against *Lygus*. Identification of specific receptors and sensory genes facilitate structural analyses and identification of ligands that could disrupt sensory genes and receptors. **(O. Perera, G. Snodgrass, C. Pierce, J. Hull (USDA-ARS, Maricopa, AZ)**

We characterized a bacterial artificial chromosome (BAC) clone of the ryanodine receptor, the target of diamide insecticides. This gene contains 109 exons and potentially contain 32 different alternatively spliced isoforms. Primers were developed for screening field populations to estimate frequencies of mutations that could lead to diamide resistance. **(O. Perera, M. Adang (University of Georgia), C. Allen, N. Little)**

Lygus lineolaris virus 2 (Llv-2) is a small RNA virus lethal to *Lygus* species. The positive sense single stranded genome of Llv-2 is 10,035 nucleotides and contains three open reading frames that codes for three different polypeptides. Electron microscopy of virus particles indicate that Llv-2 is approximately 11 nm, one of the smallest viruses to be identified. Virulence and the possibility of endophytic transmission of Llv-2 was tested using homogenates and sucrose gradient purified virus, respectively. Feeding diet mixed with homogenates of infected insects caused 100% mortality of test insects in 3 days. However, endophytic transmission was not detected in corn and cotton plants surface inoculated at two-leaf stage with purified virus particles. **(O. Perera, G. Snodgrass, C. Pierce)**

Portilla Research Program

Tarnished plant bugs, *Lygus lineolaris* (TPB), were collected from wild host plants at different locations in Mississippi, Louisiana, and Arkansas during 2015. Adults and nymphs from each location were kept individually for 15 days on solid diet and checked daily for parasitism or microbial infection. Low levels of parasitism (<1%) by *Phasia* spp. (Diptera: Tachinidae) were found in samples collected from Goodman, Mississippi. A range in parasitism of TPB from 0 to 55% was associated with two unidentified braconid species (Hymenoptera: Braconidae) in samples from Mississippi, Louisiana, and Arkansas. The highest parasitism observed was in samples from Hamburg, AR (55%) and Lake Providence, LA (27%). Larvae of *Phasia* spp emerged from parasitized TPB adults. The two braconid species emerged from adult TPB (>99%) and fourth-fifth instar nymphs (<1%). Presence of parasitism of TPB was first observed in early April with continuing observations through early June. Parasitism of TPB was not observed during the summer, but parasitism by braconid parasitoids (<1%) was again observed in late October. Natural incidence of *Beauveria bassiana*, *Metarhizium anisopliae* and *Aspergillus flavus* was also found. Measured infection rates in Mississippi, Arkansas and Louisiana ranged from 0 to 15%, 0 to 3%, and 0 to 18% for *B. bassiana*, *M. anisopliae* and *A. flavus*, respectively. Results of these studies are a component of life table studies examining ecological targets for microbial control of TPB populations. **(M. Portilla, K. Parys, A. Patterson, C. Allen, T. Ramsey and R. Luttrell)**

The median lethal concentration, sporulation and doses of two strains of *Beauveria bassiana* including the Mississippi Delta native NI8 ARSEF8889 isolated from TPB and strain KUDSC-001 ARSEF13136 isolated from Kudzu bug *Magacopta cribraria*, collected in South Carolina were estimated in assays of mixed-sex second, third, fourth, fifth instar nymphs and adults of kudzu bugs. A technic developed to evaluate *B.*

bassiana against TPB were used to bioassay the insects. Insects were collected from kudzu plants near Yazoo City, MS. Serial dilutions of four test concentrations of NI8 and KUDSC strains ($n \times 10^7$, $n \times 10^6$, $n \times 10^5$, $n \times 10^4$ spores/ mL) were prepared to treat kudzu bug adults and nymphs to evaluate mortality and infection. LC₅₀, LS₅₀ and LD₅₀ values were obtained. Differences in mortality and sporulation were found among kudzu bugs stages. Higher mortality and sporulation was observed in kudzu bugs treated with *B. bassiana* strain KUDSC. (M. Portilla, K. Parys, T. Ramsey, and R Luttrell).

Field experiments were conducted to evaluate the effects of temperature and sunlight on viability of the Mississippi Delta native NI8 strain of *Beauveria bassiana*. Field plots of eight rows wide and 50' long (0.0306 acres) were planted with BGII cotton and sprayed with *B. bassiana* early in the morning (8:00 am) with a multi-sprayer tractor calibrated to deliver 6.5×10^{12} spores / acre. Detailed observations were made on the effect of solar radiation by releasing 30 2-d old TPB adults in cages with excised branches of cotton plants cut from the plots at 0, 2, 4, 6, 8, 10, 24, 26, 28, 30, 32, 48, 50, 52, and 54 hours after applications. One cotton top branch per row (eight per plot) was cut at each evaluation time. Insects on sprayed branches were left for 24 hours in cages. Each adult was individually placed into diet cups. Insects were held in an environmental room at 27°C, 65%RH, and 12L: 12D photoperiod. Insects were examined daily for ten day for sporulation. Differences in mortality and sporulation of TPB exposed to sprayed cotton branches collected at 0 hours (69%) were significant among treatments. Mortality and sporulation drastically decreased from 1.4-fold by the next 4 hours (48%) to 9.2-fold on branches collected 10 hours after the next 10 (7.5%). However, sporulation increased 3.3-fold the next day (25%) (24 hours evaluation), decreasing 2.5-fold by the next 10 hours (10%). Less than 10% sporulation was found in bugs caged on branches collected two days after *B. bassiana* application. Overall, these results indicated that *B. bassiana* application could decrease survival of TPB when bugs were exposed to treated cotton. However, its inability to survive solar radiation, affect the use of this entomopathogenic fungus for the control of the TPB. The observation of >69% mortality of TPB adults obtained by contact indicates that this fungus may be an attractive alternative for TPB control. (M. Portilla, N. Little, T. Ramsey, and R. Luttrell)

Preliminary field experiments were carried out to determine the activity of *Beauveria bassiana* as a fungal endophyte. Seeds of corn, soybean and cotton (1 kg each) were surface sterilized in 1.5% sodium hypochlorite for 10 min and rinsed twice in sterile distilled water. Half of the seeds (500 g each) were then immersed in a 6×10^{12} mL⁻¹ suspension of *Beauveria bassiana* for 2 hours. Remaining seeds were immersed in 0.04% Tween-80 solution for 2 hours. Group of corn, soybean, and cotton seeds (both fungus treated and untreated) were planted in field plots 4 rows wide and 25' long. Three plants per row per treatment were collected each week for 4 weeks beginning 14 days after planting. Collected plants were surface sterilized and rinsed as mentioned above. Small parts of each plant were cut (node, internode, vegetative branch, petiole, blade, and stem) and inoculated on plates of Sabouraud Dextrose Agar Primix (SDAY) and incubated for 3 days. Sporulation was found in each part of the cotton, corn, and soybean plants collected from the field at the third week after planting. However, only mycelium was obtained after the second to fourth week of collection. Cotton leaves with obvious presence of external mycelium were exposed to TPB adults, but no mortality effects were observed. (M. Portilla, N. Little, T. Ramsey, and R. Luttrell)

The SIMU Insect Rearing group maintained production of 50,000 eggs per day for four species: *Helicoverpa zea* (CEW), *Heliothis virescens* (TBW), *Spodoptera frugiperda* (FAW) and *L. lineolaris* (TPB). Different stages of each insect (eggs, larvae, pupae, and adults), mixed dry diet, and diet in plastic cups were provided to USDA scientists to complete their research projects. Over 10,000 first instar larvae of CEW were inoculated individually on diet solo cups and provided for the Future Scientist Program in 2015. These insects were shipped for teaching purposes and distributed to thousand of school kids across the U. S. (H. Winter, E. Winder, M. Portilla, R. Luttrell, and Tabatha Nelson)

Zhu Research Program

A risk assessment of spray toxicity for 42 commonly used row crop pesticides to Adult Honey Bees was conducted. More than 40 pesticides are currently recommended and frequently used for foliar sprays on row crops, especially cotton. Cotton has a long (2 months) blooming period. Foraging honey bees may be killed when they are directly exposed to foliar sprays, or they may take contaminated pollen back to hives that may be toxic to other adult bees and larvae. To assess acute toxicity against the honey bee, we used a modified spray tower to simulate field spray conditions that would include direct whole-body exposure, inhalation, and continuing tarsal contact and oral licking after a field spray. A total of 42 formulated pesticides, including one herbicide and one fungicide, were assayed for acute spray toxicity to 4-6-day old workers. The ratios of field use concentration to LC₁ (lethal concentration that incurs 1% bee mortality) and LC₉₉ (lethal concentration that incurs 99% bee mortality) were adopted as a way to assess practical and real risk of 42 pesticides in honey bees. Results have been published in Journal of Economic Entomology, and they immediately attracted media attention. The value of this research included (1) development of toxicity baselines of 42 commonly used pesticides that will facilitate further studies on pesticide toxicology in honey bees; (2) Those data, particularly the ratios of field application rates to lethal concentrations of each pesticide, provide a quantifying scale that can help extension specialists and farmers select pesticides that will maintain effective control of target pests and minimize the risk to foraging honey bees. (Y.C. Zhu, J. Adamczyk, J. Yao, R. Luttrell)

The acute toxicity, sub-lethal toxicity, and potential synergistic toxicity of eight representative pesticides was measured against honeybees using spray and feeding treatments. One insecticide from each class (organophosphate, pyrethroid, carbamate, neonicotinoid, novel insecticide), a fungicide, and a herbicide were tested individually and in combination with imidacloprid, currently the most widely used insecticide. Honey bees were treated once or twice a week for up to 52 days. Mortality data were collected, and survivors were subjected to analyses of esterase, glutathione S-transferase, phenoloxidase, and invertase activities. Results indicated that imidacloprid (Advise 2FL) mainly acts as a nerve toxin, and incurs no significant bee mortality or adverse physiological impact on bees below ppm levels (maximum residual levels found so far) based on limited experiment data. Most other pesticides at residual levels did not synergize imidacloprid toxicity against honey bees, but synergistic toxicity was detected after the concentrations of each pesticide was increased. (Y.C. Zhu, J. Yao, J. Adamczyk, R. Luttrell)

2016 Research Plans

Adams Research Plans

In 2016, SIMRU will continue to participated in the 2016 NSCG Sweetpotato variety trials at the Alcorn State University Research Farm in Mound Bayou, MS. (L. Adams, C. Johnson)

The twenty-fourth year effort to monitor and report populations of *H. zea* and *H. virescens* in the Mississippi Delta through pheromone trapping will be continued at the same sample-sites. Weekly data will be provided to the Mississippi Cooperative Extension Service to alert farmers to pest threats. (**L. Adams, C. Johnson**)

As redirection of research efforts within USDA-ARS, SIMRU transforms during the 2016 growing season we will increase our participation with other USDA-ARS, SIMRU scientists with two studies: 1) monitor the movement and use of *Beauveria bassiana* for control of tarnished plant bugs in mustard, corn and cotton and 2) study the effect of imidacloprid seed treatment on honey bee movement and foraging in cotton, corn and soybean plots. (**R. Luttrell, N. Little, C. Allen, M. Portilla, L. Adams**)

Allen Research Plans

The spatial and temporal distribution of various stink bug and lepidopteran species in wild hosts and soybean in the MS Delta will continue to be examined. (**C. Allen, L. Andrews**)

The susceptibilities of major lepidopteran pests of the mid-South to various insecticide will be measured through field and laboratory assays. (**C. Allen, N. Little, R. Luttrell, K. Dixon, J. Warren, L. Andrews**)

The impact of insecticide seed treatments on early-season insect populations will further be accessed. (**C. Allen, L. Adams, N. Little, R. Luttrell, K. Parys, C. Johnson, L. Andrews**)

An evaluation of sprayed and unsprayed plots for lepidopteran and stink bug pests in early and late planted soybean and cotton at different levels of infestation and the subsequent impact on yield within production fields will be conducted. (**C. Allen, L. Andrews, N. Little, D. Adams, R. Luttrell**)

Little Research Plans

Annual assessments of insecticide resistance of multiple populations of key heliothine pests of cotton, corn, and soybean to commercially available Bt toxin combinations will be conducted. This will include screening for physiological changes in heliothines associated with exposure to conventional and transgenic insecticides and their effect on survival in field environments. These data will be correlated to field studies to determine the effectiveness of pyramided-gene Bt crops for controlling heliothines. (**N. Little, M. Mullen, C. Allen, R. Luttrell, D. Adams, and L. Bell**)

Sentinel plot and large field cage evaluations of pyramided-gene Bt cotton under sprayed (threshold) and unsprayed conditions relative to heliothine control will continue. Field performance data from these experiments will be correlated with results from laboratory and plant-based assays. (**N. Little, M. Mullen, C. Allen, R. Luttrell, and D. Adams**)

Evaluations of microbial insecticides (NPVs) will continue in non-Bt and transgenic Bt cottons using a conventional and a system sensitive approach with regard to preserving beneficial insects. This approach may allow us to reap the benefits of a natural, undisturbed system for the control of heliothines. (**N. Little, R. Luttrell, C. Allen, D. Adams**)

Economic evaluations of Bt trait packages in corn for the control of corn earworms will continue and consist of numerous sentinel locations throughout the MS Delta. (**N. Little, D. Cook, and D. Adams**)

Luttrell Research Plans

Work initiated in 2015 to evaluate different assay procedures to measure susceptibility of *H. zea*, *H. virescens*, *S. frugiperda* and *L. lineolaris* to insecticides and Bt toxins will be completed. Much of this work was conducted to better link laboratory measurements of insect susceptibility to field application rates and expected field mortality rates. Comparisons of insect survival and leaf consumption on Bt and non-Bt cotton leaves on agar in plastic cups appeared to be a reasonable approach to measuring survival of larvae exposed to Bt cottons expressing multiple Bt toxins. Similarly, research with cotton leaves dipped in varying concentrations of formulated insecticide appeared to be a useful method to project insect mortality given contact with known deposits of insecticide. Greenhouse and field production of assay materials provides a potential year around opportunity to conduct assay experiments. This work is being continued and modified in the Allen, Little and Portilla laboratories as they have assumed unit-wide responsibilities for monitoring insect resistance to insecticides (Lepidoptera), Bt crops, and insecticides (*L. lineolaris*), respectively. The Luttrell group will finish the preliminary studies and transfer the results to the responsible SIMRU scientists.

SIMRU has accumulated a backlog of unpublished research information following the departure of previous scientists (Snodgrass and Jackson). Much of the research initiated with these previous scientists was continued with the remaining research staff under the temporary supervision of Luttrell. Nearly all of this work has now been assumed by new SIMRU scientists, but there is considerable information that needs to be summarized and published to bridge the previous research effort to the new research program. This includes existing data on tarnished plant bug susceptibility to insecticides, activity of *Beauveria bassiana* on tarnished plant bug in cotton, C3 and C4 isotope analyses of *H. zea* moths across the southeastern U.S., susceptibility of lepidopteran pests to Bt toxins over the past five years, and oversprays of Bt cotton with insecticides. Luttrell will work with the previous and new scientists to get this information summarized and published in 2016. Similarly, Luttrell has several previous research projects initiated at the University of Arkansas, including topics associated with Bt resistance and farm-scale management systems, that need to be summarized and published.

Clint Allen and Randy Luttrell are working with Tom Sappington (ARS Ames, IA), Louis Hesler and Sharon Papiernik (ARS Brookings, SD) to conduct a meta-analysis and summary document on insecticide seed treatments in U.S. field crops. This is component of a NP-304 research effort to examine the impact of seed treatments on pollinators.

With the expected retirement of Larry Adams in 2016, Luttrell will work with Chris Johnson to maintain limited field research on sweetpotato insects. This will include participation in the National Sweet Potato Variety Trials. They will also work with the Allen and Little groups to explore residual activity of neonicotinoids seed treatments in cotton, corn and soybean and alternative thrips management systems in cotton. Additionally, they will provide support of Allen, Little, and Parys groups conducting a large plot study to study impacts of treated and untreated soybean seed on pollinators, insect and crop production. As needed, they will support a coordinated field study among the Allen, Little, Portilla and Zhu groups to measure residual activity of several foliar applied insecticides against a range of pest and beneficial species.

Parys Research Plans

Overwintering populations of *L. lineolaris* on senescing vegetation will be collected to determine the proportion of adults overwintering in differing habitat types, and to monitor the appearance of the F1 generation. (**K. Parys, C. Roberts**)

Further collections of apoid pollinators will be made in the delta region of Mississippi. An increased attention on pollinator issues in agricultural areas makes documenting the fauna especially important.

Collections will be made through the same methods as the previous summer, with the addition of some collection locations on National Wildlife Refuges. (**K. Parys, N. Little, K. C. Allen, M. Portilla, D. Cook**)

Evaluating the usefulness of potential pheromone blends for trapping and monitoring efforts will focus on trap designs, pheromone blends, and deployment strategies for optimized use. (**K. Parys, C. Roberts**)

Adult *L. lineolaris* will be collected from agricultural fields in addition to wild host plants in order to determine movement throughout the season using stable carbon isotope analysis. Data will be analyzed using the R packages SIBER and SCIAR. (**K. Parys, L. Price, C. Roberts**)

Perera Research Plans

High-throughput genome re-sequencing of *H. zea* and *H. armigera* is planned for conducting genome-wide association studies (GWAS) and genome best linear unbiased prediction (gBLUP) to identify genetic loci contributing to insecticide and Bt toxin tolerance. [**O. Perera**]

Transcriptome sequences of *H. zea* will be used to profile gene expression patterns in Cry1Ac tolerant and susceptible insect strains. R script pipeline developed for tobacco budworm will be adapted to identify gene regulatory networks *H. zea*. [**O. Perera**]

Portilla Research Plans

Laboratory studies will be conducted in order to obtain life tables and growth rates estimations for TPB from the field and lab colonies.

New microbial control agent isolated from *L. lineolaris* collected from field will be bioassayed to evaluate pathogenetic action on TPB adults. Bioassays will be conducted to evaluate the virulence and compare them with NI8. LC₅₀s and LD₅₀s will be estimated.

In order to complete the impact of biological control on TPB seasonal abundant and distribution, further collection of TPB will be made from one more year from wild host plants and in cultivated crops at four different locations within the Mississippi Delta. Collection will be made through the same method used the previous year.

Field research sites will be established on commercial farms in the Mississippi Delta at the interface (field borders) of cotton and adjacent fields of corn and early season soybean. Multiple applications will be made (*Beauveria bassiana* alone and in combination with Novaluron) on two-week intervals as long as densities of TPB are detecting in the corn or flowering soybean.

The insect rearing unit will continue its production in order to provide material for researchers and for the Future Scientist Program. In addition, three more insect rearing units will be used for maintaining field colonies of FAW, CEW, TBW and TBP.

Zhu Research Plans

We will examine detoxification systems in honey bees. Southern row crops are frequently sprayed with five different classes of insecticide, including organophosphates, pyrethroids, carbamates, neonicotinoids, and some novel insecticides. As same as other insects, honey bees may be or may be not able to evolve detoxifying systems to adapt and tolerate different insecticides. Candidate enzymes/genes associated with

metabolic detoxification include cytochrome P450 oxidases (P450), esterases (Est), and glutathione S-transferases (GST). Understanding the detoxification mechanisms in honey bees may help minimizing bee exposure and poisoning through selection of less bee-antagonistic chemicals in pest management.

Objectives: (1) Assay biological response of honey bees to P450 inhibitor piperonyl butoxide (PBO), Est inhibitor S,S,S-tributylphosphorotrithioate (DEF), and GST inhibitor diethyl maleate (DEM) to reveal which enzyme is mainly responsible for detoxifying representatives of 5 insecticide classes, including Bracket (acephate), Karate (Lambda-Cyhalothrin), Vydate (oxamyl), Belay (clothianidin), and Tracer (spinosad). Insecticide (formulation) will be diluted to concentration of LC20. Honey bee workers (25/cage, 5-7 d old) will be pre-treated (spray) with 1% inhibitor solution (PBO, DEF, DEM), and bees will be sprayed with insecticide solution one hour after inhibitor treatment. Mortality will be recorded 48-h after insecticide treatment. (2) Examine enzyme activities: First bee samples will be collected one hour after inhibitor treatment, and 2nd bee sample will be collected 12 and 48 hours after insecticide spray. Enzyme activities will be measured using plate reader and protocols described previously.

We will examine the interaction of Varroa mites and pesticides in honey bees. The varroa mite (*Varroa destructor*), ectoparasites that feed on the hemolymph of immature and adult honey bees, is the world's most devastating pest of Western honey bees. Varroa mites can transmit multiple viruses that may cause the majority of the damage (Webster and Delaplane 2001). Varroa and viral infestations may alter bee's vigorousness and then susceptibility to pesticides. Understanding the interaction of Varroa mites (virus) and pesticides may lead to the development of integrated management strategy to enhance honey bee health.

Objectives: (1) Investigate whether mite and viral infestations synergize pesticide toxicity at sub-lethal (residue) levels using feeding treatment of young bees (2-3 days old workers); (2) By using spray treatment to reveal the adverse impact of mite and viral infestation on the susceptibility of foraging bees (3 wk old) to different pesticides. **Procedures:** (1) Obtain healthy bees using ApiVar treatment in March and August; (2) Monitor mite population and virus titer; (3) Dose-response assay or discrimination dose assay; (4) Enzyme activity assay, including phenoloxidase, esterase, glutathione S-transferase, and invertase.

The non-safe period of continuous exposure of honey bee to spray residues on plants will be accessed. Foliar spray is frequently applied on row crops, especially on cotton. Foraging bees may be directly exposed to sprays or continuously exposed to pesticide residues after sprays. Different insecticides have different length of residual toxicity in field conditions. Revealing the non-safe period of different pesticides may help insecticide selection to minimize the killing of foraging bees. **Objectives:** (1) Examine the acute toxicity of pesticide residues to foraging (3 wk old) bees by exposure caged bees every other days to excised fresh plant leaves after spraying; (2) Analyze real-time (the time bees start to contact leave) pesticide residues in plant leave and establish a relationship of pesticide residue levels with honey bee mortality for each pesticide tested. **Procedures:** (1) Select one commonly recommended/used insecticide from each insecticide class; (2) Spray cotton in July; (3) Collect leave for bioassay and residue analysis.

2015 Trust Fund or Reimbursable Cooperative Agreements

Project Title: Variability in Host Use by Soybean Pests: Field Collections of *Helicoverpa zea* *Heliothis virescent* and *Chrysodeixis includens*

Agreement No.: 58-6402-3-037T

ARS Investigator: Clint Allen

Project State Date: 7/1/2013

Project Funded By: Monsanto

Project Investigator: Samuel Martinell

Project End Date: 6/30/2018

2015 Accomplishments:

Pheromone traps were established in two counties in Mississippi: Coahoma and Washington Counties during the 2015 growing season. At each location, 6 traps were placed at the interface of a field of Bt cotton

and soybean. Traps were baited with synthetic pheromone of three different moth species: corn earworm, *Helicoverpa zea*, tobacco budworm, *Heliothis virescens*, and soybean looper, *Chrysodeixis includens* (two traps for each species). Moths were collected and pheromone was changed in traps on a weekly basis from June through September at both locations. Moths that were in good shape were placed individually into vials and shipped to Monsanto Company where they are being analyzed to determine host of larval development.

2016 Research Plans:

Plans are pending.

Project Title: Biology of and Management Strategies for Redbanded Stink Bug, an Emerging Threat to US Soybean Production

Agreement No.: 58-6402-4-022R

ARS Investigator: Clint Allen

Project State Date: 1/1/2014

Project Funded By: LSU AgCenter

Project Investigator: Jeff Davis

Project End Date: 12/31/2016

2015 Accomplishments:

The regional and alternate hosts of redbanded stink bugs were examined in Louisiana, Mississippi and Texas during 2015. Stink bugs were sampled when daily mean temperatures exceeded 15°C. Various species of clover still appear to be the most important spring hosts in the build-up of redbanded stink bug populations, but hosts utilized between clover and the movement into soybeans need further examination. In soybean in Mississippi, green and brown stink bugs were the predominate species encountered during 2015. Redbanded and southern green stink bugs were found sporadically and numbers increased in some late planted soybean fields during August and September. Insecticide susceptibilities of kudzu bugs were examined in adult vial tests with technical grade insecticides to monitor their susceptibilities to commonly used pyrethroid and organophosphate insecticides.

2016 Research Plans:

The same studies will be conducted for a third year in 2016.

Project Title: Assessment of Natural Refuge for *Lygus lineolaris*

Agreement No.: 58-6402-3-041T
ARS Investigator: Katherine Parys
Project State Date: 8/1/2014

Project Funded By: Monsanto
Project Investigator: Doug Sumerford
Project End Date: 7/31/2019

2015 Accomplishments:

Densities of *L. lineolaris* were collected and monitored by using a combination of sweeping and using sticky traps in and around a commercial field of cotton to determine abundance. Information collected included about pesticide application in field, phenological stage of cotton plants in the field, surrounding potential host plants, and weather information was recorded at each collection site and date. Additional abundances of *L. lineolaris* were collected from wild host plants at locations in the same general area to compare with populations in cotton.

2016 Research Plans:

Plans are pending, but will be similar to plans from 2015.

2015 Specific Cooperative Agreement Research Accomplishments

Project Title: Low input systems of pest control for sweetpotato in the Mississippi Delta

Alcorn State University

Project Investigator: Tahir Rashid

Project State Date: 8/1/2011

Agreement No.: 58-6402-1-614

ARS Investigator: Randall Luttrell

Project End Date: 7/31/2016

2015 Accomplishments:

Organic sweetpotato research

Four organic sweetpotato varieties (All Purple, Beauregard, O'Henry, Porto Rico) were planted in RCBD in ASU Ext/Research Demonstration Farm, Mound Bayou, MS. Each variety was planted in 4 replicated plots each with 20 sweetpotato plants in two rows. Drip irrigation was used to establish plants. Six replications of purple sheet traps coated with insect glue were installed around the experimental field. The traps were checked biweekly; samples collected, identified and counted. Soil traps baited with crimped oats were used to sample larval populations. Eight soil traps were installed in each of two sweetpotato fields, checked biweekly and larvae identified. Six multifunnel traps constructed with purple sheets were installed around sweetpotato research fields to collect live adult click beetles. Weed control within and around the plots was accomplished by hoeing and gas powered push tiller. All treatment plots were harvested at maturity. Prior to harvest sweetpotato vines were collected from one row (10 plants) of each plot and weighed. One row from each test plot was harvested and sweetpotato roots were evaluated for yield and insect damage. Roots were differentiated into jumbo grade, US No. 1 and canners. Insect damage to roots was determined by specific feeding marks of white grubs, wireworms, 12-spotted cucumber beetle, sugarcane beetle and flea beetles. Roots damaged by more than one insect were categorized as multiple insect-damage. Thickness of root periderm of each sweetpotato variety was measured by taking random samples for any relationship to insect feeding damage.

Results

Overall insect-feeding damage differed significantly among different varieties. Porto Rico had the highest damage (58.5%) compared to O' Henry (24%), All Purple (17.5%) and the Beauregard (13.2%) where the lowest damage was observed. Percent damage by the 12-spotted cucumber beetle and wireworm was significantly different among varieties. All Purple showed the highest resistance to the wireworm feeding damage. Porto Rico had the highest multiple insect damage after O' Henry. The other two varieties, All Purple and Beauregard had significantly less multiple insect feeding damage than Porto Rico and O' Henry. Weight of sweetpotato vines also differed significantly among different varieties. All Purple had the highest vegetative mass. Beauregard had the lowest weight of vines than all other varieties. Periderm thickness was measured as 167.5 μm (O' Henry), 130.7 μm (All Purple), 129.9 μm (Beauregard) and 73.2 μm (Porto Rico).

Effect of Microbial formulation on insect damage and yield of sweetpotato

Sweetpotato variety Beauregard was planted in replicated field plots each consisting of 4 rows and 50 ft long to evaluate the effect of a microbial formulation, SumaGrow on root development, yield and insect damage. Insect pest populations were monitored with purple sheet sticky traps throughout the growing season. Biweekly sweetpotato plant samples were taken from each plot to evaluate development over

growing season. Each sample consisted of 6 sweetpotato plants excavated in entirety. The root mass and size were recorded. The vine length and weight were also taken to evaluate vegetative growth. All experimental plots were harvested and roots evaluated for insect damage and yield.

Results

The insect feeding damage and sweetpotato yield did not differ between treated and non-treated plots.

Survey of wireworm larvae in sweetpotato

Soil bait traps containing steamed crimped oats soaked overnight were installed in commercial and research sweetpotato fields to collect wireworm larvae. Each treatment bait was dispensed in a 6.5 cm diameter and 13 cm deep hole made with a bulb planter. The bait grains inside each hole were covered with soil and encircled with a 15 cm diameter and 15 cm long PVC pipe painted orange for later retrieval. Each sampling area consisted of 4 rows X 45 m. with four sampling points. One soil trap was installed at each sampling point. Each of two locations had 16 soil bait traps in four sampling areas. The samples were collected weekly by digging each trap site and brought back to the laboratory for counting and identification.

Results

Very low numbers of wireworm larvae were collected in soil samples.

Presentation in Professional Conference

Effect of Microbial formulation on sweetpotato growth and yield, and insect damage to the roots

T. Rashid, R. Luttrell, V. Njiti and L. Adams. Scheduled for National Sweetpotato Collaborators Group Annual Meeting in San Antonio, TX. February 2016.

Extension Presentations and Publications

1. Effect of SumaGrow microbial formulation on Beauregard sweetpotatoes. Abstract in field day program and in-field presentation, Alcorn State University, Extension/Research and Demonstration Center, Mound Bayou, MS.
2. Comparison of yield and insect damage to organic sweetpotatoes in the Mississippi Delta. Abstract in field day program and in-field presentation, Alcorn State University, Extension/Research and Demonstration Center, Mound Bayou, MS.

2016 Research Plans:

During 2016 research experiments will be repeated.

Project Title: Transgenic crop efficacy against target pests in agronomic crops

Mississippi State University
Project State Date: 08/01/2013
Project Investigator: Jeff Gore

Agreement No.: 58-6402-3-039
Project End Date: 08/01/2018
ARS Investigator: Nathan Little

2015 Accomplishments:

Multiple paired plantings of non-Bt and VT Double Pro hybrids from the same hybrid family were conducted over time. There were no significant differences in numbers of small, medium, or total larvae between the non-Bt and VT Double Pro hybrids. The VT Double Pro hybrid had significantly lower densities of large earworm larvae compared to the non-Bt hybrid.

Trials (early-normal planting window, and late-later than the normal planting window) were conducted to evaluate the performance of commercially available Bt corn technologies. These included Genuity VT Double Pro, Optimum Leptra, Optimum Intrasect and Herculex. To minimize the impact on genetic background (genetics other than Bt traits), technologies were compared to a non-Bt hybrid from the same hybrid family (Genuity VT Double Pro vs. related non-Bt hybrid and Optimum Leptra, Optimum Intrasect and Herculex vs. related non-Bt hybrid). Generally, corn earworm infestation levels were lower than observed in previous years

For the early planted trial there were no significant differences between the Genuity VT Double Pro hybrid and the non-Bt hybrid from the same hybrid family for numbers of small, medium, or total corn earworm larvae. Also, there were no differences between the Optimum Leptra, Optimum Intrasect, Herculex hybrids and the related non-Bt hybrid for small corn earworm larvae. Plots planted to the Genuity VT Double Pro hybrid had significantly fewer large larvae compared to the related non-Bt hybrid. Also the Optimum Leptra hybrid had significantly fewer medium corn earworm larvae compared to the Optimum Intrasect, Herculex hybrids and the related non-Bt hybrid. The Optimum Leptra hybrid had significantly fewer medium larvae compared to the Herculex hybrid. The Optimum Leptra hybrid had significantly fewer medium corn earworm larvae compared to the Optimum Intrasect, Herculex and the related non-Bt hybrid. There were no significant differences in damaged kernels between the Genuity VT Double Pro and the non-Bt hybrid from the same hybrid family or between the Optimum Leptra, Optimum Intrasect, or Herculex hybrids and the non-Bt hybrid from the same hybrid family. There were no significant differences in yield between the Genuity VT Double Pro hybrid and the non-Bt hybrid from same hybrid family or between the Optimum Leptra, Optimum Intrasect, or Herculex hybrids and the non-Bt hybrid from the same hybrid family.

For the late planted trials there were no significant differences between the Genuity VT Double Pro hybrid and the non-Bt hybrid from the same hybrid family for numbers of small corn earworm larvae. The Optimum Leptra hybrid had significantly fewer small and total corn earworm larvae compared to the Optimum Intrasect, Herculex and the related non-Bt hybrid. Plots planted to the Genuity VT Double Pro hybrid had significantly fewer medium, large, and total larvae compared to the non-Bt hybrid from the same hybrid family. There were no significant differences in number of damaged kernels between the Genuity VT Double Pro hybrid and the non-Bt hybrid from the same hybrid family or between the Optimum Leptra, Optimum Intrasect, or Herculex hybrids and the non-Bt hybrid from the same hybrid family. There were no significant differences in yield between the Genuity VT Double Pro and the non-Bt hybrid from same hybrid family or between the Optimum Leptra, Optimum Intrasect, or Herculex hybrids and the non-Bt hybrid from the same hybrid family.

An experiment was conducted in 2015 to quantify the level of efficacy of currently available transgenic Bt cotton technologies. The treatments were in a split-plot arrangement with four replications. The main-plot factor was insecticide spray and included plots sprayed with two applications of chlorantraniliprole or unsprayed plots. The sprayed plots were sprayed at first flower and the second application was made approximately two weeks after the first application. The sub-plot factor was Bt cotton type and included non-Bt, Bollgard II, Widestrike, TwinLink, and Widestrike 3. The number of damaged squares and bolls was recorded on multiple dates throughout the flowering period. For reporting purposes, the mean levels of square and boll injury were calculated across all samples. All plots were harvested at the end of the season and yields were converted to pounds of lint per acre.

Overall, bollworm pressure was high in this experiment. Averaged across the whole season, square damage in non-Bt cotton was 17.5 per 40 squares (44%) and boll damage was 6.5 per 40 bolls (16%). In terms of square damage, significant differences were observed among the different Bt technologies (Table 1). All technologies, including the sprayed non-Bt, had significantly lower square damage than the unsprayed non-Bt cotton. For all technologies, the use of insecticide sprays significantly reduced the level of square damage relative to unsprayed plots. Similar results were observed with boll damage. In terms of yield, all of the Bt technologies had greater yields in the sprayed plots relative to the unsprayed plots of the same technologies except Widestrike 3. These data suggest that insecticide sprays may be needed all of the Bt technologies to prevent economic losses.

Table 1. Mean levels of square damage and boll damage in currently available Bt cotton technologies at the Delta Research and Extension Center in 2015.

Cotton Technology	Mean Square Damage (No. per 40)	Mean Boll Damage (No. per 40)	Lint Yield (lb. per Acre)
Non-Bt Unsprayed	17.5 a	6.5 a	783 e
Widestrike Unsprayed	10.4 b	3.4 b	974 d
Widestrike 3 Unsprayed	4.0 de	1.8 d	1084 bcd
Bollgard II Unsprayed	2.0 fg	1.8 d	984 d
TwinLink Unsprayed	5.8 c	2.5 c	1007 cd
Non-Bt Sprayed	5.1 cd	1.5 de	1197 ab
Widestrike Sprayed	3.0 ef	0.9 ef	1306 a
Widestrike 3 Sprayed	1.1 gh	0.0 g	1144 bc
Bollgard II Sprayed	0.3 h	0.0 g	1185 ab
TwinLink Sprayed	1.5 g	0.4 fg	1181 ab

Means within a column followed by the same letter are not significantly different.

2016 Research Plans:

These studies will be repeated in 2016.

Project Title: Transgenic crop efficacy against target pests in agronomic crops

Mississippi State University

Project State Date: 08/01/2013

Project Investigator: Fred Musser

Agreement No.: 58-6402-3-038

Project End Date: 08/01/2018

ARS Investigator: Clint Allen

2015 Accomplishments:

Cotton

Methods: Bollgard II cotton (DP 1321 B2RF) was planted beside non-Bt cotton (DP 174 RF) on 2 planting dates (May 12 and June 18, 2015) in Starkville, MS. Plots were at least 8 rows wide and 200 ft long. The cotton was grown using typical agronomic practices. No insecticides were applied to the cotton. At harvest, 10 row ft of cotton was hand harvested from each of three sections of each variety for each of the planting dates. Harvested sections were parallel to each other and each harvested section was treated as a replicate. Lint per acre was estimated assuming a lint turnout of 40%.

Results: All measured parameters were statistically better in the Bollgard II varieties than the check varieties except for % missing bolls (Table 1). The number of boll positions was significantly higher in the Bt variety, suggesting that some of the difference in yield was due to agronomic potential differences of the varieties, and not the Bt toxin. However, the percentage of bolls with insect damage was less in the Bt plots, indicating that the Bt varieties are still providing protection against some boll feeding pests.

Table 1. Harvest data from 2015 Bt- non-Bt cotton comparison, Starkville, MS. Statistical analysis included planting date as a random factor.

Planting Date	Treatment	Yield (lb lint/ac)	# Boll Positions	% Good Bolls	% Damaged Bolls	% Missing Bolls
12-May	Bt	1238 ± 218	197 ± 14	62.2 ± 4.1	13.7 ± 3.7	24.1 ± 4.0
	Non-Bt	1100 ± 250	138 ± 19	52.5 ± 4.2	31.3 ± 2.6	16.2 ± 4.4
18-June	Bt	1669 ± 223	450 ± 24	57.0 ± 2.9	16.7 ± 2.3	26.3 ± 2.3
	Non-Bt	1247 ± 135	301 ± 26	44.8 ± 4.3	28.6 ± 1.4	26.7 ± 3.3
Overall P-values		0.019	0.008	0.044	0.002	0.389

Corn

Methods: Nine hybrids of corn were planted on May 4, 2015 in Starkville, MS. Hybrids included 3 non-Bt hybrids (Dekalb 64-27 and Dekalb 64-82 and Pioneer 1319R), a Smartstax hybrid (Dekalb 64-87) expressing Cry1A.105, Cry1F and Cry2Ab2, a VT3 hybrid (Dekalb 64-24) expressing Cry1Ab, a VT2P hybrid (Dekalb 64-89) expressing Cry1A.105 and Cry2Ab2, a Herculex hybrid (Pioneer 1319HR) expressing Cry1F, an Optimum Intrasect hybrid (Pioneer 1319YHR) expressing Cry1F and Cry1Ab, and an Optimum Leptra hybrid (Pioneer 1319VYHR) expressing Cry1Ab, Cry1F and Vip3A. Smartstax also had Bt genes active against rootworms. Plots were 8 rows wide by 40 ft long with 4 replications and a 10 ft gap between replicates.

When corn had dried down and was nearing harvest, 20 consecutive ears from one row were examined for tip kernel damage, other kernel damage, and ear feeding that did not appear to damage any kernels. The amount of each type of damage was estimated in cm². Two rows of corn that were not used for any other purpose were harvested from each plot during the normal corn harvest period using a plot combine. Yield, moisture and test weight were recorded.

Results: Southwestern corn borer feeding and fall armyworm feeding were not monitored in this trial, but southwestern corn borer pheromone traps caught very few moths at the field, and defoliation by fall armyworm was not at a level normally considered to be economically damaging. Corn earworm feeding was the focus of this study. Corn earworm normally feed at the ear tip, and tip damage varied significantly. The only events to have less ear damage than any of the non-Bt hybrids were Herculex, Intrasect and Leptra, the three Pioneer Bt hybrids (Table 2). Damage at other locations on the ear also varied, with Leptra consistently having the least damage. Most importantly, yield was significantly higher on the Bt varieties than on the non-Bt varieties. This was largely driven by one variety of non-Bt corn that yielded poorly.

Table 2. Harvest data from 2015 Bt- non-Bt corn comparison, Starkville, MS

Bt event	Yield (bu/ac)	No Insect feeding on ear (% ears)	Tip damaged kernels (cm ²)	Other damaged kernels (cm ²)	Non-kernel damage (cm ²)
Non-Bt 1	167 ± 15ab	0.0 ± 0.0b	11.4 ± 1.9ab	1.0 ± 0.3bc	0.5 ± 0.2
Non-Bt 2	100 ± 17c	0.0 ± 0.0b	13.4 ± 1.9a	1.5 ± 0.3b	0.6 ± 0.3
Non-Bt 3	150 ± 15ab	0.0 ± 0.0b	12.8 ± 1.4a	2.8 ± 0.5a	0.8 ± 0.4
VT Triple	132 ± 26bc	1.3 ± 1.3b	11.0 ± 0.9abc	1.7 ± 0.6b	0.4 ± 0.1
VT Double Pro	145 ± 9ab	1.3 ± 1.3b	9.9 ± 2.0abc	0.8 ± 0.2bc	0.5 ± 0.3
Smartstax	180 ± 16a	1.3 ± 1.3b	8.1 ± 0.9bcd	0.9 ± 0.4bc	0.5 ± 0.3
Herculex	155 ± 17ab	7.5 ± 7.5b	7.7 ± 2.1cd	1.5 ± 0.7b	0.6 ± 0.3
Intrasect	161 ± 27ab	1.3 ± 1.3b	6.3 ± 0.7d	0.7 ± 0.1bc	0.7 ± 0.2
Leptra	178 ± 19a	67.5 ± 11.8a	0.9 ± 0.5e	0.1 ± 0.1c	0.1 ± 0.1
P-value: Trt	0.004	<0.001	<0.001	0.002	0.76
Bt vs non-Bt	0.034	<0.001	<0.001	0.004	0.34

2016 Research Plans:

Plans for 2016 are to continue comparing Bt technologies to non-Bt technologies in corn and cotton as done in 2014 and 2015. To better encompass the variety of agronomic and insect situations facing growers in Mississippi, we plan to place some trials at Brooksville and potentially at Verona as well as at Starkville.

Project Title: Conduct an Analysis of Previous Bt Crop Efficacy

Mississippi State University

Project Investigator: Fred Musser

ARS Investigator: Nathan Little

2015 Accomplishments:

Dr. Daniel Fleming was hired in August, 2015 to conduct a meta-analysis of the published literature regarding field efficacy of Bt toxins against corn earworm (*Helicoverpa zea*), tobacco budworm (*Heliothis virescens*) and fall armyworm (*Spodoptera frugiperda*). Searches for articles reporting data for corn and cotton varieties expressing transgenic Bt events with comparison to non-Bt varieties were begun in September 2015. Searches were conducted using the following terminology: *Bacillus thuringiensis* and *Helicoverpa zea* and *Gossypium hirsutum*; *Bacillus thuringiensis* and *Helicoverpa zea* and *Zea mays*; *Bacillus thuringiensis* and *Heliothis virescens* and *Gossypium hirsutum*; *Bacillus thuringiensis* and *Spodoptera frugiperda* and *Gossypium hirsutum*; *Bacillus thuringiensis* and *Spodoptera frugiperda* and *Zea mays*. Search engines queried with these search terms were: Google Scholar, EBSCO, Oxford University Press, Science Direct, Scopus, PubMed, BioOne, Web of Knowledge, and the Beltwide Cotton Conference proceedings. Currently, there are over 3,750 referred journal articles, conference proceedings, and theses/dissertations that have been identified and databased in EndNote. Of these, over 2500 have been examined to date to determine if they contain relevant data. To be considered relevant, the data must meet the following criteria: 1) must have a comparison to a non-Bt variety; 2) must be events MON810, TC1507, MON89034, Bt11, MIR162, or a combination thereof in corn, and must be events MON531, MON15985, MXB-13, or a combination thereof in cotton; 3) work must have been conducted with natural insect populations in field plots, with wild natural insect populations and field grown plant tissue but conducted in lab, or with lab reared (\leq F3 generation from wild) insects infested in field plots. This has currently yielded over 1500 Bt to non-Bt comparison for corn and over 750 comparisons for cotton drawn from approximately 150 papers. Additional papers may be found by searching the reference section of the papers used, as well as, sending current corn and cotton researchers a list of articles we have found and asking them if they know of any additional articles.

2016 Research Plans:

We plan to finish the data entry for cotton and corn and begin data analyses for publications.

2015 Publications and Presentations

Publications

1. Arias, R.S., M. Portilla, J.D. Ray, C.A. Blanco, S.A. Simpson, and B.E. Scheffler. 2015. Ecology, Behavior and Bionomics First Genotyping of *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) Progeny from Crosses between Bt-Resistant and Bt-Susceptible Populations, and 65-Locus Discrimination of Isofamilies. *Journal of Botanical Sciences*. 4 (1):18-29 (Submitted January 4, 2015)
2. Luttrell, R.G. _____. Introduction (Cotton Insects and Their Management). *Compendium of Cotton Diseases, Pests and Disorders*. (SP received September 17, 2015) (Submitted September 23, 2015)
3. Luttrell, R.G., T.G. Teague, and M.J. Brewer. 2015. Cotton insect pest management. Pp. 509-546. In D.D. Fang and R. G. Percy (Eds.) *Cotton. Agronomy Monograph 57*, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI. (CW received November 24, 2014) (Submitted November 25, 2014) (Acceptance November 25, 2014)
4. Parys, K.A., A.D. Tripodi, and B.J. Sampson. 2015. The giant resin bee, *Megachile sculpturalis* Smith: new distributional records for the Mid-and Gulf-south USA. *Biodiversity Data Journal*. 3:e6733. DOI: 10.3897/BDJ.3.e6733 (SP received September 15, 2015) (Submitted September 23, 2015) (Acceptance October 20, 2015)
5. Parys, K.A., and G.L. Snodgrass. 2015. Comparison of degree-day accumulation models for predicting spring reproductive populations of *Lygus lineolaris* (Palisot de Beauvois). *Midsouth Entomologist*. 8(1):61 (CW received October 7, 2014) (Accepted February 23, 2015) (Abstract Only)
6. Parys, K.A., G.L. Snodgrass, R.G. Luttrell, K.C. Allen, and N. Little. 2016. Baseline susceptibility of *Lygus lineolaris* (Hemiptera:Miridae) to novaluron. *Journal of Economic Entomology*. 109 (1):339-344. DOI: 10.1093/jee/tov318 (SP received July 8, 2015) (Submitted July 13, 2015) (Accepted October 14, 2015)
7. Parys, K.A., S. Tewari, and S. Johnson. 2015. Adults of the waterfern weevil, *Stenopelmus rufinus* Gyllenhal (Coleoptera: Curculionidae) feed on a non-host plant *Salvinia minima* Baker, in Louisiana. *Coleopterist's Bullentin*. 69(2):316-318 DOI: <http://dx.doi.org/10.1649/0010-065X-69.2.316> (CW received July,8 2014) (Submitted July 15, 2014)
8. Perera, O. P., J. Gore, G. L. Snodgrass, R. E. Jackson, K. C. Allen, C. A. Abel, and R. G. Luttrell. 2015. Temporal and spatial genetic variability among tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), populations in a small geographic area. (CW received September 26, 2015) (Submitted August 21, 2014) (Accepted December 5, 2015) *Ann. Entomol. Soc. Am.* 1–12 (2015); DOI: 10.1093/aesa/sau016

9. Perera, O.P., K.C. Allen, D. Jain, M. Purcell, N.S. Little, and R.G. Luttrell. 2015. Rapid identification of *Helicoverpa armigera* and *Helicoverpa zea* (Lepidoptera:Noctuidae) using ribosomal RNA internal transcribed Spacer 1. *Journal of Insect Science*. 15(1):155. DOI:1093/jisesa/iev137. (SP received August 6, 2015) (Submitted August 7, 2015) (Accepted October 10, 2015)
10. Perera, O.P., K.S. Shelby, H.J.R. Popham, F. Gould, M.J. Adang, and J.L. Jurat-Fuentes. 2015. Generation of a transcriptome in a model lepidopteran pest, *Heliothis virescens*, using multiple sequencing strategies for profiling midgut gene expression. *PLoS One*. 10(6):e0128563. doi:10.1371/journal.pone.0128563 (CW received September 8, 2014) (Submitted September 9, 2014)
11. Perera, O.P., T.K. Walsh, and R.G. Luttrell. _____. Complete mitochondrial genome of *Helicoverpa zea* (Boddie) and expression profiles of mitochondrial-encoded genes in early and late embryos. *Journal of Insect Science*. (CW received November 20, 2014) (Submitted November 19, 2015) (Accepted March 7, 2016)
12. Portilla, M., G.S. Snodgrass, D. Street, and R.G. Luttrell. 2015. Demographic parameters of *Nezara viridula* (L.) (Heteroptera:Pentatomidae) reared on two diets developed for *Lygus* spp. *Journal of Insect Science*. 15(1):165. doi:10.1093/jisesa/iev144 (SP received September 23, 2015) (Submitted September 25, 2015) (Accepted October 29, 2015)
13. Portilla, M., H.K. Abbas, and C. Accinelli. 2015. Evaluation of *Beauveria bassiana* spores compatibility with a sprayable bioplastic formulation to control the tarnished plant bug. *Midsouth Entomologist*. 81(1):62 (CW received October 20, 2014) (Abstract Only)
14. Portilla, M., W.A. Jones, O.P. Perera, N. Seiter, J. Greene, and R.G. Luttrell. _____. Evaluation of three isolates of *Beauveria bassiana* for control of (Heteroptera: Plataspidae). *Environmental Entomology*. (SP received September 15, 2015) (Submitted September 18, 2015)
15. Seymour, M., O.P. Perera, H.W. Fescemyer, R.E. Jackson, S.J. Fleischer, and C.A. Abel. _____. Peripheral genetic structure of *Helicoverpa zea* indicates asymmetrical panmixia. *Ecology and Evolution*. (SP received September 22, 2015) (Submitted September 25, 2015) (Accepted March 09, 2016)
16. Seymour, M., K. Seppala, E. Machler, and F. Altermatt. _____. Lessons from the Macroinvertebrates: species-genetic diversity correlations highlight important dissimilar relationships. *Ecography*. (SP received September 3, 2015)
17. Shelby, K.S., O.P. Perera, and G.L. Snodgrass. 2015. Expression profiles of astakine-like transcripts in the tarnished plant bug, *Lygus lineolaris*, exposed to fungal spores of *Beauveria bassiana*. *Insect Mol. Biol.* DOI:10.1111/imb.12175 · 2.98 (CW received August 24, 2014) (Submitted August 26, 2014)

18. Zhu, Y.C., C. Blanco, M. Portilla, J. Adamczyk, R. Luttrell, and F. Huang. _____. Evidence of multiple/cross resistance to Bt and organophosphate insecticides in Puerto Rico population of the fall armyworm, *Spodoptera frugiperda*. Pest Management Science. (CW received April 11, 2014) (Submitted April 15, 2014) (Accepted January 12, 2015)
19. Zhu, Y.C., J.J. Adamczyk, T.E. Rinderer, J. Yao, R.G. Danka, R.G. Luttrell, and J. Gore. 2015. Spray toxicity and risk potential of 42 commonly used formulations of row crop pesticides to adult honeybees (Hymenoptera:Apidae). Journal of Economic Entomology. 1-8, DOI: 10.1093/jee/tov269. (SP received March 30, 2015) (Submitted April 12, 2015) (Accepted August 20, 2015)
20. Zhu, Y. C., and R. G. Luttrell. 2015. Altered gene regulation and potential association with metabolic resistance development to imidacloprid in the tarnished plant bug, *Lygus lineolaris*. Pest Management. (CW received June 23, 2013) (Submitted June 26, 2013) (Accepted February 10, 2014) Sci. 71:40-57. (Published 2014 online DOI 10.1002/ps.3761)
21. Zhu, Y.C., J. Yao, J.J. Adamczyk, and R.G. Luttrell. _____. Synergistic toxicity of imidacloprid with seven representative pesticides against honey bees. Midsouth Entomologist. (SP received September 25, 2015) (Abstract Only)

Presentations

1. Adams, L.C. and C. Johnson. 2015. 2014 USDA-ARS, Southern Insect Management Research Unit Sweetpotato Variety Trials and 2015 Entries. 2015 Growers Meeting, Alcorn State University Research Farm. Mound Bayou, MS. April 14, 2015.
2. Adams, L.C. and C. Johnson. 2015. Mississippi Delta On-Farm Evaluation of Yield Response to Recommended Insecticide, Nematicide and Herbicide Applications. 2015 Growers Meeting, Alcorn State University Research Farm. Mound Bayou, MS. April 14, 2015.
3. Adams, L.C., and C. Johnson. 2015. Mississippi Delta On-Farm Evaluation of Yield Response to Recommended Insecticide, Nematicide and Herbicide Applications. National Sweetpotato Collaborators Group Meeting. Nashville, TN. January 24-25th, 2015. [Poster]
4. Allen, K.C., R. Luttrell, N. Little, and K.A. Parys. 2014. Within-population variability in responses to insecticide bioassays. 61st Annual Meeting of the Entomological Society of America. Portland, OR. November 16-19, 2014. [Poster]
5. Dixon, K., A. Patterson, R. Luttrell, M. Portilla, and K. Parys. 2015. Measurements of tarnished plant bug susceptibility to major insecticide classes in the Mississippi Delta during 2014. Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015. (poster presentation)
6. Johnson, S.J., M. Ferro, M.J. Grodowitz, K.A. Parys, and W. Lorio. 2014. Control of water lettuce (*Pistia stratiotes* L.) (Araceae) with water lettuce weevil (*Neohydronomus affinis* Hustache) (Coleoptera: Curculionidae) in Louisiana. 61st Annual Meeting of the Entomological Society of America. Portland, OR. November 16-19, 2014. [Poster]
7. Little, N., D. Adams, K. C. Allen, and R. Luttrell. 2014. Assessing impacts of supplemental control for heliothines on pyramided-Bt and non-Bt cottons. Entomological Society of America, Portland, OR. November 16, 2014.
8. Little, N., K. C. Allen, R. Luttrell, and D. Adams. 2015. Supplementary control of bollworms (*Helicoverpa zea*) in Bt and non-Bt cottons. Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015. (poster presentation)
9. Luttrell, R. G. 2014. Tarnished plant bug research at USDA/ARS. Special Meeting of the Delta Council Advisory Research Committee, B. F. Smith Auditorium, Delta Research and Extension Center, Mississippi State University, Stoneville, MS. December 12, 2014. (Invited)
10. Luttrell, R. G. 2015. Research needs related to insecticides and pollinators from an ARS perspective. Delta Council and Environmental Protection Agency Meeting on Neonicotinoids, Pollinators, and Relevant Issues, B. F. Smith Administration Building Auditorium, Delta Research and Extension Center, Mississippi State University, Stoneville, MS. January 21, 2015. (Invited)
11. Luttrell, R. G., N. Little, O. P. Perera, K. C. Allen, M. Portilla, F. R. Musser, D. Cook, and J. Gore. 2014. Monitoring perspective for tobacco budworm and bollworm in the Mid-South. Entomological Society of America, Portland, OR. November 16, 2014. (Invited) (presentation made by Nathan Little)

12. Mullen, M., R. Luttrell, N. Little, O.P. Perera, and K.C. Allen. 2015. Susceptibility of *Helicoverpa zea* and *Heliothis virescens* to commercial formulations of *Bacillus thuringiensis* and lyophilized tissue from Bt crops. Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015. (poster presentation)
13. Parys, K.A. 2014. Working for the federal government: Studying what ‘bugs’ the American people. Member Symposium: Finding the best fit for you: career opportunities for entomologists in industry, academia, military, and government. 61st Annual Meeting of the Entomological Society of America. Portland, OR. November 16-19, 2014. [20 min talk]
14. Parys, K.A., and G.L. Snodgrass. 2014. Comparison of degree-day accumulation models for predicting spring reproductive populations of *Lygus lineolaris* (Palisot de Beauvois). Midsouth Entomologist Meeting. Starkville, MS. October 21, 2014. (CW received October 20, 2014)
15. Parys, K.A., and G.L. Snodgrass. 2015. Comparison of degree-day accumulation models for predicting spring reproductive populations of *Lygus lineolaris* (Palisot de Beauvois). Beltwide Cotton Conferences. San Antonio, TX. January 5-7, 2015. [Poster]
16. Parys, K.A., K.A. Renken, G.L. Snodgrass, and K.C. Allen. 2014. Influence of landscape heterogeneity on insecticide resistance in *Lygus lineolaris* (Palisot de Beauvois). 61st Annual Meeting of the Entomological Society of America. Portland, OR. November 16-19, 2014. [Poster]
17. Parys, K., T. Mascari, and N. Little. 2015. Evaluation and efficacy of oral biomarkers for *Lygus lineolaris* (Palisot de Beauvois). Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015. (poster presentation)
18. Perera, O.P., G.L. Snodgrass, and R.G. Luttrell. Characterization of *Wolbachia* endosymbiont of *Lygus lineolaris*. Society for Invertebrate Pathology Annual Meeting. (SP received April 16, 2015) (Abstract Only)
19. Perera, O.P. and J.J. Becnel. The complete genome of *Aedes sollicitans* nucleopolyhedrovirus. Society for Invertebrate Pathology Annual Meeting. (SP received April 16, 2015) (Abstract Only)
20. Perera, O.P., K.S. Shelby, and G.L. Snodgrass. Expression profiles of the tarnished plant bug digestive genes. 48th Annual Meeting of the Society for Invertebrate Pathology. (SP received September 30, 2015) (Abstract Only)
21. Portilla, M., H.K. Abbas, and C. Accinelli 2014. Evaluation of *Beauveria bassiana* spores compatibility with a sprayable bioplastic formulation to control the tarnished plant bug. Midsouth Entomologist Meeting. Starkville, MS. October 21, 2014 (CW received October 20, 2014)
22. Portilla, M., N. Little, C. Solorzano-Torres, C. Granadino, and R. Luttrell. 2015. Bioassay for estimation of medial lethal concentration and doses of several insecticides to control tarnished plant bug in cotton. Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015. (poster presentation)

23. Portilla, N. Little, C. Solorzano-Torres, C. Granadino, and R. Luttrell. 2015. Laboratory evaluation of novaluron and pyriproxyfen, insect growth regulators against late nymphs and young adults of tarnished plant bug on solid artificial diet. Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015. (poster presentation)
24. Rashid, Tahir, P. J. McLeod, and R. Luttrell. 2014. Efficacy of different insect traps in sweetpotato. Entomological Society of America, Portland, OR. November 18, 2014. (poster)
25. Rashid, Tahir, P. J. McLeod, and R. Luttrell. 2014. Insect monitoring in sweetpotato. Southeastern Branch, Entomological Society of America. Greenville, SC. March 3, 2014.
26. Seymour, M., and O.P. Perera. 2015. Temporal and habitat influences on population genetics of *Helicoverpa Zea* (bollworm). (SP received June 30, 2015) (Abstract Only)
27. Zhu, Y. C., J. J. Adamczyk, and R. Luttrell. 2015. Spray toxicity and risk assessment of 42 commonly used pesticides to honey bees. Southeastern Branch Entomological Society of America, Biloxi, MS. March 17, 2015.
28. Zhu, Y.C., J.J. Adamczyk, and R.G. Luttrell. 2014. What you should know about pesticides: Which is more toxic and which is relatively safer to your honeybees. Arkansas Beekeepers Association Annual Conference. Mountain View, AR. October 9-12, 2014. (CW received October 23, 2014)

Appendix A

SIMRU's 2015 Pathway Interns/LA Appointments Employees



Top left to right: Severino, Signa, Megan Holley, Robert L. Adams II, Shundalyn Moore, Mamadou Fadiga, Jonathan Clerk-Beamon, Sariah Warren, Mi'Shayla Johnson, Kenneth Wells, John-Austin Coleman, Shawnee Gundry, Gerard Winters, Jana' Slay, Chris Brent, Kaleb Murry, John Wiltcher IV, Jacob Smith, Raksha Chatakondi, Manuela Jojoa, Robert Hurt III, Kyle Scott, Dillon Robinson, Nicholas Hart Manus, Emily Bodin **Not pictured:** Jaret Reister, Russell Godbold, Marcus Cannon, Cadarius Cannon, Collin Salley, Maria Benavides